ENVIRONMENTAL IMPACTS OF MACROECONOMIC AND SECTORAL POLICIES

Edited by
Mohan Munasinghe

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The International Society
for Ecological Economics (ISEE)
The World Bank
and
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Foreword

Over the past decade, there has been a fundamental change in the way in which governments and development agencies think about the environment and development. It is increasingly accepted that the overarching goal should be sustainable development which has three basic elements. In addition to the conventional goal of economically efficient allocation of scarce resources, the environmental objective of maintaining a healthy, resilient, and sustainable ecological life support system, as well as the social goals of fair distribution of resources (intragenerational and intergenerational), maintenance of cultural capital and empowerment, are recognised as equally important and interdependent. This balanced approach to sustainable development is particularly crucial.

In particular, economic development and environmental protection are no longer regarded as mutually exclusive goals. Rather, it is now recognised that a healthy environment is essential to sustainable development and a strong economy. Moreover, economists and planners are increasingly aware that economic development which erodes natural capital is often not successful. In fact, macroeconomic policies and development strategies and programs which do not take adequate account of the state of critical resources — such as forests, soils, grasslands, freshwater, coastal areas, and fisheries — may degrade the resource base upon which future growth is dependent.

The papers in this volume are particularly useful since they come at a time when the environmental impacts of macroeconomic policies have come under close scrutiny. They look at the ecological and social impacts of structural adjustment programs and other macroeconomic policies in an integrated way. The volume also goes beyond the "ex-post" approach of merely tracking impacts, to an "ex-ante" viewpoint which begins to consider the fully integrated ecological, economic, and social system in the initial design of development policies. This broader, "ecological economics" approach necessarily involves transdisciplinary co-operation that, while difficult, is increasingly being recognised as essential.

Concern for environmental impacts is also a key component of a broader effort by the World Bank to focus on the links between environment and development. Due to the complexity of policy-environment interactions, Environmental Impacts of Macroeconomic Policies takes an empirical, case-study-oriented approach, including thorough reviews of current work both within and outside the Bank. Specific case studies from Africa, Asia and Latin America underscore the difficulties of developing a general methodology to trace the environmental impacts of policy reform, yet offer evidence that empirical work may help identify and deal with the most important potential environmental impacts.

The papers in this volume were presented at a session at the 1994 biannual meeting of the International Society of Ecological Economics (ISEE), in San Jose, Costa Rica (except for the paper by Panayotou and Hupe, which was presented at a joint UNEP-World Bank Workshop on the Environmental Impacts of Structural Adjustment Programs held in New York in March 1995). The session was co-sponsored by the World Bank and organised and chaired by Mohan Munasinghe.

Approximately 1,300 people attended the ISEE meetings, from a broad range of academic disciplines and policy perspectives. This attests to the growing interest in ecological economics and sustainability, and the concerted effort that is now going into developing an integrated understanding of ecological, economic, and social systems and linkages. It will be particularly important to begin to quantify these linkages, and many of the papers in this volume are aimed in that direction.

We still have a long way to go, but our vision of the goal is now coming into proper focus — thanks to the efforts of the authors represented in this volume, as well as other researchers. Integrated models and policies can help us to see and act on the sometimes subtle and hidden interconnections between the ecological, economic and social parts of the system. With this clearer vision we can begin to design a sustainable and desirable development path, and use macroeconomic policies to effectively help us achieve that goal.

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An Overview of the Environmental Impacts of Macroeconomic and Sectoral Policies

Mohan Munasinghe

In recent times, there has been a growing awareness of the complementarities between sustainable development and a healthy environment. This period has also witnessed major political, social, and economic changes as many countries have embarked on a radical structural transformation of their economies. Thus, an examination of the environmental implications of macroeconomic and sectoral policies of an economywide nature has become a matter of considerable relevance and urgency. This volume is based on a set of papers presented and discussed at a special session on this subject, jointly organized by the World Bank and the International Society for Ecological Economics (ISEE), during the annual international conference of the ISEE in San Jose, Costa Rica in October 1994.

During the past decade, structural adjustment programs (SAPs) have been perceived as one of the most powerful forms of macroeconomic intervention in the developing world. Therefore, in the next section of this overview we briefly review the background to SAPs. Next, to place such economic reforms within the context of the broader development process, some emerging concepts of sustainable development and the role of environmental economics are discussed. The overview continues with a brief analysis of some key economy-environment linkages. Finally, there is a review of the papers in the rest of this volume.

Background to structural adjustment programs

For many developing countries the 1980s represented a period of economic hardship. Internal mismanagement of economies, combined with external economic factors that were beyond their control, caused a situation now commonly referred to as the "debt crisis." The major oil price increases of 1974 and 1979 were a significant shock to most of these countries, which depended heavily on imported oil. Furthermore, restrictive monetary policies were adopted by Western countries during the late 1970s and early 1980s to curtail their own inflation rates. This caused real interest rates to rise and made it very difficult for developing countries to service their debts. As a result, developing countries experienced balance of payment difficulties, which forced them to rely even more heavily on foreign donors. Economic growth rates declined and some countries even experienced negative growth.

The International Monetary Fund (IMF) and the World Bank agreed to provide financial assistance, with the primary objective of enabling countries to service their debts. Assistance, however, was conditional on the adoption of stringent economic and fiscal reform measures designed to reorient faltering economies toward growth and development. Under a broad framework, currently referred to as structural adjustment, both short-term "stabilization" and more medium-term "adjustment" measures were agreed upon.

A major emphasis of stabilization policies was to reduce the pressure on foreign reserves by reducing domestic demand. The IMF became the most active proponent of stabilization policies. Balance of payment problems were addressed through a monetary approach. The idea was to control inflation and reduce imports by maintaining tight fiscal contractionary policies and restraining the supply of money. Simultaneously, currency devaluation policies were adopted to improve the terms of trade and make exports more competitive in international markets. Although these reforms were expected to cause short-term recessionary effects, it was argued that economic growth would resume soon as export-lead growth increased.

Adjustment policies were required to accelerate the economic recovery and growth of the export sector. These policies focused on the supply side and addressed inefficiencies of the internal economic structure. They also focused on reforming the public sector through medium- and long-term measures. Together with reform programs at the macroeconomic level, sectoral policies were adopted to improve the efficiency of resource allocation and competitiveness of markets at the sectoral level.

However, in spite of economic gains through structural adjustment, both environmental and social problems have persisted in many countries. The growing sustainable development literature is seeking to identify and remedy development strategies that lead to the unsustainable use of natural resources and the environment. One key question is whether the very economic policies being prescribed to alleviate economic problems are perhaps undermining the environmental resources and social fabric on which nations depend. In recent years a conceptual framework for sustainable development has emerged that seeks to integrate and reconcile economic efficiency, social concerns, and environmental protection (Munasinghe 1993). Environmental economics plays a key role in helping integrate these elements into conventional decision making.

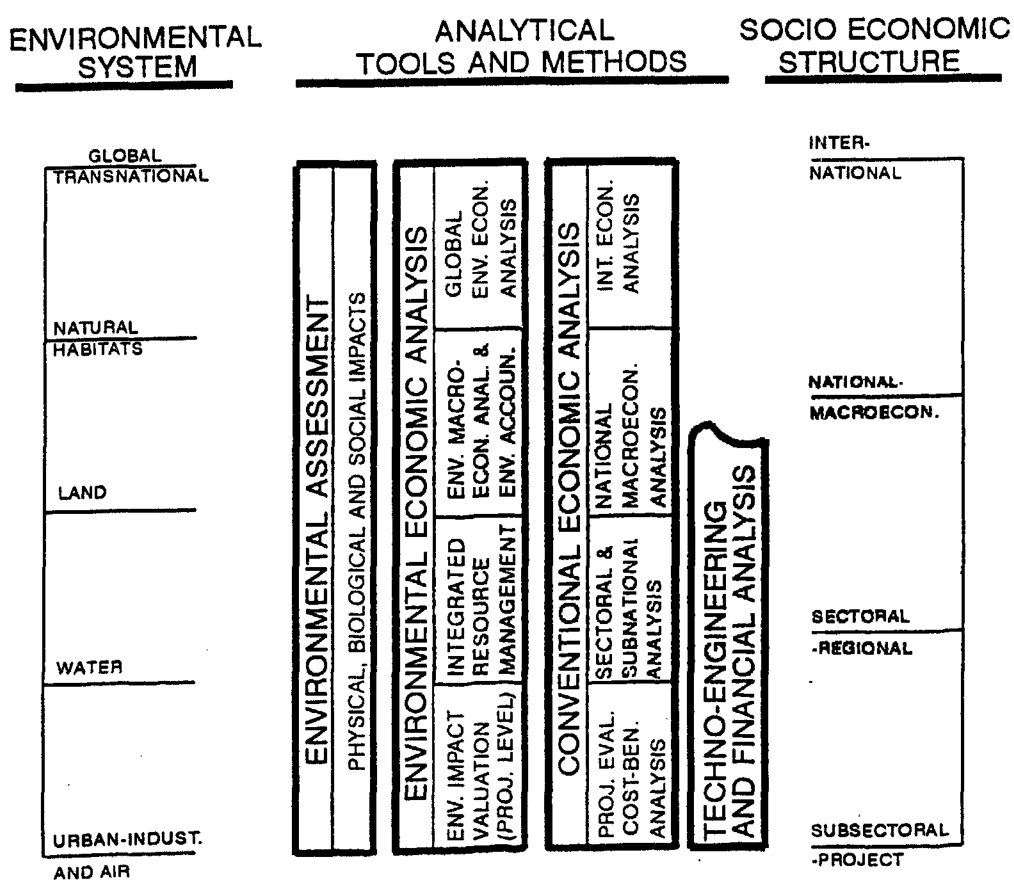
Sustainable development and the role of environmental economics

Current approaches to the concept of sustainable development draw on the experience of several decades of development efforts. Historically, the development of the industrialized world focussed on production. Not surprisingly, therefore, the model followed by the developing nations in the 1950s and the 1960s was output- and growth-dominated, based mainly on the concept of economic efficiency. By the early 1970s the large and growing numbers of poor in the developing world—and the lack of "trickle-down" benefits to them—led to greater efforts to directly improve income distribution. The development paradigm shifted toward equitable growth, where social (distributional) objectives, especially poverty alleviation, were recognized as distinct from and as important as economic efficiency.

Protection of the environment has now become the third major objective of development. By the early 1980s a large body of evidence had accumulated to show that environmental degradation was a major barrier to development. The concept of sustainable development has, therefore, evolved to encompass three major points of view: economic, social, and environmental (see Box for details). Clearly, economywide policies (although primarily aimed at improving economic performance) may have significant social and environmental impacts. While all three elements of sustainable development (economic, social, and environmental) should be treated symmetrically, this is a tremendously complex task. This volume takes a first step by focusing mainly on economic-environmental linkages. The social effects of economic policies are also discussed in several papers, as well as the further environmental impacts of such social changes (see Box at the end of this chapter).

Environmental economics helps us incorporate environmental concerns into the structure of economic decisionmaking, as shown in Figure 1.1. The right side of the diagram indicates the hierarchical nature of modern society, including the global and

Figure 1-1 Role of environmental economics in decisionmaking



transnational level consisting of sovereign nation states. The next level of the socioeconomic structure represents the multisectored macroeconomy of a country. Various economic sectors (such as industry and agriculture) exist in each economy. Finally, each sector consists of different subsectors and projects.

Unfortunately, environmental analysis cannot be carried out readily using the above socioeconomic structuring. The left side of the figure shows one convenient environmental breakdown in which the issues are: (i) global and transnational (for example, climate change, ozone layer depletion); (ii) natural habitat (for example, forests and other ecosystems; (iii) land (for example, agricultural zones); (iv) water resource (for example, river basins, aquifers, watersheds); and (v) urban-industrial (for example, metropolitan areas, airsheds). In each case a holistic environmental analysis would seek to study a physical or ecological system in its entirety. Complications arise when such natural systems cut across the structure of human society. For example, a complex forest ecosystem (such as the Amazon) or a physical resource system (a large river) could span several countries and also interact with many economic sectors within each country.

The causes of environmental degradation arise from human activity (ignoring natural phenomena) and, therefore, we begin this analysis with the right side of the figure. The physical effects of socioeconomic decisions on the environment must then be traced through to the left side. The techniques of environmental assessment (EA) have been developed to facilitate this difficult analysis. For example, destruction of a primary moist tropical forest may be caused by hydroelectric dams (energy sector policy), roads (transport sector policy), slash-and-burn farming (agricultural sector policy), mining of minerals (industrial sector policy), land clearing encouraged by land-tax incentives (fiscal policy), and so on. Disentangling and prioritizing these multiple causes (right side) and their impacts (left side) will involve a complex analysis.

Meanwhile, the usual decisionmaking process on the right side relies on techno-engineering and financial and economic analyses of projects and policies. In particular, conventional economic analysis is well developed and uses techniques such as project evaluation/cost-benefit analysis (CBA), sectoral/regional studies, multisectoral macroeconomic analysis, and international economic analysis (finance, trade, and so forth) to assist the process of decisionmaking at the various hierarchic levels.

The figure also shows how environmental economics plays its crucial bridging role, by overlaying the EA results onto the framework of conventional economic analysis. A variety of environmental economic techniques, including valuation of environmental impacts (at the local or project level), integrated resource management (at the sector or regional level), environmental macroeconomic analysis and environmental accounting (at the economywide level), and global environmental economics (at the worldwide level), facilitate this process of incorporating environmental issues into traditional decisionmaking. Because there is considerable overlap among the analytical techniques described above, this conceptual categorization should not be interpreted too rigidly.

Clearly, the formulation and implementation of such policies are difficult tasks. In the deforestation example described earlier, protecting this single ecosystem is likely to raise problems of coordinating policies in a large number of disparate and (usually) noncooperating ministries and line institutions (that is, energy, transport, agriculture, industry, finance, forestry, and so on) in several countries.

The critical linkages between human activities and the environment that are examined in this volume fall within the macroeconomic and sectoral levels indicated in Figure 1.1. Some specific issues in this context are reviewed next.

Key policy-environment linkages

Three specific linkages between economy-wide (that is, both macroeco-nomic and sectoral) policies and the environment are examined below, to demonstrate the breadth and variety of issues involved.

Environmental impacts of policies that cause income and price changes

Liberalizing economic reforms that raise resource prices and eliminate subsidies would normally be expected to reduce waste and thereby give rise to both economic and environmental gains (the so called win-win scenario). However, this may not always be the case.

First, consider a relatively stagnant economy that has open-access forest areas. Initially the demand for timber is given by the curve D_0 in Fig. 1.2. At the effective (subsidized) price p_S, which represents the marginal cost of logging, the initial rate of deforestation is Q_0. Suppose Q_L is the safe limiting rate of deforestation beyond which serious ecological damage occurs. As long as $Q_0 < Q_L$, the situation may continue undetected.

Next, suppose an economic reform package stimulates growth and shifts the timber demand curve outward to D_1. This "income effect" could be the result of increased domestic demand (for example, timber required by a construction boom) and/or higher timber exports (for example, due to trade liberalization and devaluation that make such exports more profitable). The deforestation rate could quickly shift to Q_S, greatly exceeding the safe limit Q_L and causing serious environmental harm.

Clearly, the remedy is not to stop growth but rather to establish a proper market price for timber. As a first step, property rights may need to be reestablished in open-access areas and an "efficient" stumpage fee imposed—to eliminate the economic subsidy (ES) and correctly reflect the opportunity cost of the timber. The resulting efficient price (p_E) would reduce the logging rate to Q_E, which still exceeds Q_L. The next step might be to impose an additional externality cost (EC) that reflects the loss of biodiversity or damage to watersheds and thereby establish the full environmentally adjusted price (p_{EN}). The deforestation rate would now fall to $Q_{EN} < Q_L$.

Exactly analogous reasoning would apply if we considered fuel prices and polluting emission from urban transport. In this case, p_S might be a subsidized diesel price, p_E the equivalent import (or export) opportunity cost, p_{EN} the full price, including a tax to cover the externality cost of air pollution, and Q_L the health-determined safety standard.

This rather simple example helps to clarify how the expansionary effects of economic reform policies could combine with hitherto neglected economic distortions to cause environmental harm. The parallel introduction of complementary measures that address the specific distortions would allow the broader reforms to go forward without adverse environmental impacts. The additional environmental measures would need to be built (ex ante) into the reform package rather than introduced as an afterthought.

Environmental Kuznets curve

The previous example raises the issue of increased environmental burdens imposed by growth and greater resource use. Nevertheless, growth is a prime imperative for developing countries—especially ones with large numbers of poor and destitute people. Fig. 1.3 represents a stylized view of the environmental Kuznets-curve argument—that resource degradation or pollution will increase initially with growth and then eventually decline.

The question of the existence of the curve is not the relevant one. Even if such a curve characterized past growth, there is no reason for countries to passively accept "historical determinism" along their future development path. Thus, a poor country starting at A needs

Figure 1–2 Environmental impacts of policies via income and price changes

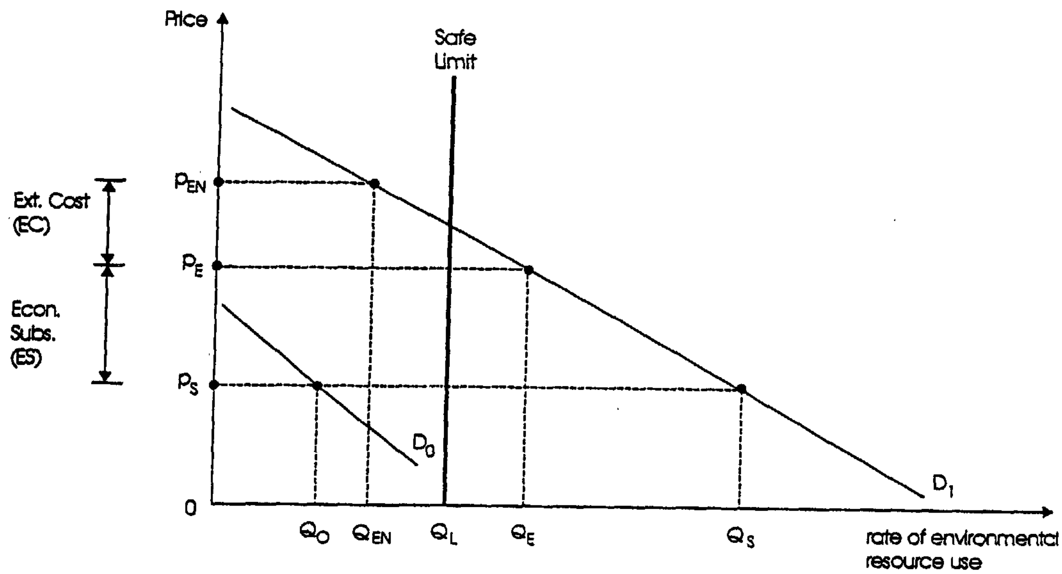
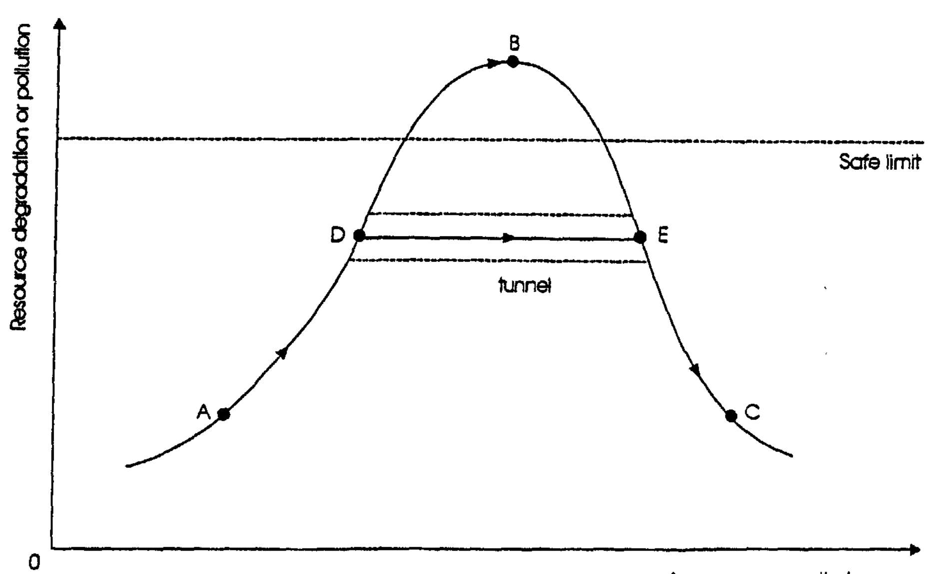


Figure 1–3 Tunneling through the environmental kuznets curve



Source: Munasinghe M., "Making Economic Growth More Sustainable", *Ecological Economics*, Vol. 15, pp 121-4, 1995.

not feel obliged to pass through the peak of environmental degradation at B in order to reach C. As discussed in the previous section, the effective articulation of growth-oriented policies with appropriate complementary measures could help to alter the structure of growth and limit environmental harm. In effect, lower-income countries could learn from the experience of wealthier nations and adopt policies that permitted them to "tunnel" through the curve (along the path DE in Figure 1-3).

Timing and sequencing of policy reforms

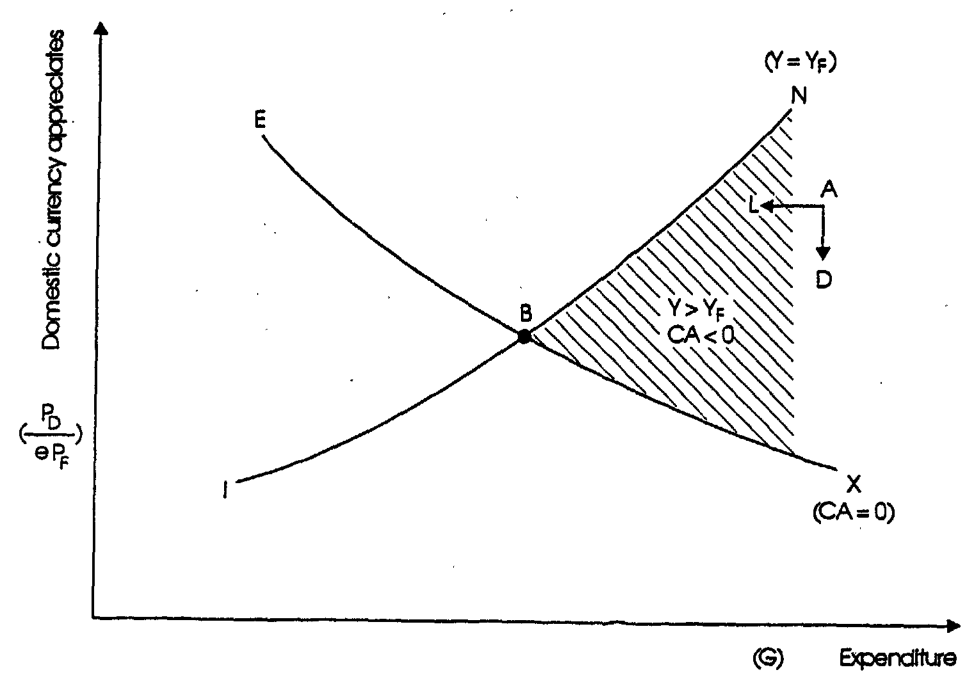
Up to now we have not seriously considered altering economywide policies merely to achieve environmental objectives but instead have chosen to rely on specific complementary measures to mitigate environmental harm. For illustrative purposes, however, suppose that the environmental damage due to an economic reform program is likely to be rather large. In such a case, is it possible to adjust the timing and sequencing of macroeconomic and sectoral policy tools to avoid the worst environmental consequences?

There is a growing body of literature that seeks to examine the pros and cons of timing and sequencing stabilization and adjustment measures—to achieve economic goals (for a recent review, see Edwards 1992) but not environmental ones. One may adapt some of this past work to obtain basic insights that help to deal with environmental issues.

Consider Figure 1.4, in which the X-axis indicates aggregate expenditure in a national economy (for example, government expenditure) and the Y axis reflects the effects of domestic currency appreciation (for example, the ratio of domestic goods prices to foreign goods prices weighted by the exchange rate). Suppose that the initial state of the economy is at point A (within the shaded quadrant), below the line of internal balance (IN) and above the line of external balance (EX). In this situation, economywide policy reforms would seek to move the economy toward the equilibrium point B by reducing both the current account deficit (since CA < O) and the excess demand (since $Y > Y_F$).

A movement in the (downward) direction AD could be achieved by a currency devaluation and removal of trade barriers, while a shift in the (leftward) direction AL would occur if government subsidies were eliminated (for example, by raising subsidized

Figure 1–4 Timing and sequencing macroeconomic reforms



Source: Munasinghe M., "Making Economic Growth More Sustainable", *Ecological Economics*, Vol. 15, pp 121-4, 1995.

P_D = price of domestic goods
P_F = price of foreign goods
e = exchange rate
IN = internal balance equilibrium
EX = external balance equilibrium
Y = income
Y_F = full employment income
CA = current account
G = government expenditure

energy prices). Suppose that the reforms affecting AD could be achieved first and AL somewhat later, due to powerful vested interest (for example, transport or industrial lobbies). In this case, trade liberalization alone might lead to greater foreign investment and expansion of energy-intensive industries, resulting in excessive use of (still subsidized) energy and more pollution.

Clearly, the foregoing analysis is limited by its simple, static, and short-term nature. Nonetheless, some environmentally-related arguments such as the above could be used to fruitfully reexamine (and perhaps modify) the timing and sequencing of policy reforms. Since hardly any work has been carried out in this area, and country circumstances vary widely, it would not be possible to generalize. At the same time, restraint and good judgment are required to avoid the temptation of making major changes in economywide policies merely to achieve minor environmental (and social) gains. Once again, policy options that achieved "win-win" gains would be the most desirable.

Overview of the volume

The papers in this volume are organized in three broad sections. Chapters 2 to 6 deal with general links between the environment and economywide policies and broad development strategies. The next three papers deal with sector-specific environmental issues relating to trade, agriculture, and energy. The volume concludes with country case studies of Botswana and Costa Rica.

Munasinghe and Cruz describe the findings of a set of twelve World Bank country case studies. While cautioning about the complexity of the issues involved and the difficulties of generalizing, the authors argue that liberalizing economic reforms that free up prices and eliminate wasteful resource use are good for both the economy and the environment. However, residual market, policy, and institutional imperfections can cause environmental harm unless specific complementary measures are adopted (ex ante) to mitigate the damage. Similarly, short-term policies that restore stability and encourage a long-term perspective are good economically and environmentally. Nevertheless, government budgetary cutbacks may fall disproportionately on environmental (and social) protection programs. Special attention is required to avoid such an outcome. Finally, longer-term effects of growth have important environmental effects via impacts on poverty, employment, incomes, and prices.

The authors also set out a practical approach based on the action impact matrix (AIM), which helps to build synergies between economic and environmental policymakers, and develop a consensual analytical framework linking economywide policies and critical environmental issues. Finally, the paper provides a five-point implementation program for decisionmakers involving screening, analysis, remediation, follow-up, and integration of economic and environmental strategies.

In their paper, Panayotou and Hupé focus specifically on structural adjustment programs. They argue that the question is not whether to undertake structural adjustment but what kind of structural adjustment, at what pace, and in which sequence. Structural adjustment programs must pay as much attention to market and institutional failures as they pay to policy failures. Using environmental and social policies as add-ons or as supplementary and compensatory or parallel policies to mitigate or cushion the environmental and social impacts of structural adjustment is second best compared to the full integration of these policies with the economic reforms in the context of a sustainable development strategy.

These authors further conclude that structural adjustment programs can best ensure sustainability by providing for reinvestment of rents from the depletion of natural resources in natural, environmental, manmade, and human capital, to maintain and expand the productive capacity of the economy and the quality of life. Partial reforms or incomplete implementation of reforms may do more harm than good if they are selectively applied to benefit certain constituencies without due regard to their social and environmental impacts. The missed opportunities of the past should serve as valuable lessons for the future rather than as reminders dwelling on the assignment of blame for past failures (with a great deal of hindsight).

Next, Postigo indicates that it is difficult to predict whether macroeconomic policies have a positive or negative impact on the environment because the links between macroeconomic policies and the environment are indirect and therefore difficult to substantiate. Nevertheless, sectoral and specific economic policies, and the institutional context in which these policies are implemented, are more important than macroeconomic policies in determining the extent of environmental degradation. Particularly crucial is the institutional capacity of the state to implement precisely the targeted economic policies compatible with the protection of the environment and to enforce environmental regulations.

The author also concludes that there is no evidence that the change to an export-oriented strategy of economic development necessarily brings about greater environmental damage. Some adjustment programs have put strong pressure on indebted countries to service their external debt, resulting in the acute impoverishment of the lower-income populations and institutional collapse of the state. The need to increase foreign exchange earnings may have also created a greater pressure on the natural resource base of some developing countries.

Mäler and Munasinghe use an explicit mathematical model to explore the circumstances in which macroeconomic policies might be modified to address environmental issues. They argue that we live in a second-best world, and it is this fact that gives rise to macroeconomic policy failures vis-à-vis the environment. If it is found that the environmental side effects will be substantial, either the root causes (market failures or property rights problems) should be addressed, or if that is not feasible, the macroeconomic policy should be appropriately modified in order to reduce losses.

The authors indicate that the impacts on the environment from changes in macroeconomic policies are channeled most often through rather complex and less direct mechanisms in the economy. In order to identify these side effects, general equilibrium analysis has proven to be quite valuable. In spite of the rather severe problems with the accuracy of available data in computable general equilibrium models, these models are at the present the only tools available that can help identify relevant second-best problems when macroeconomic policies are developed. Therefore, the authors conclude that an active program of amalgamating macroeconomic objectives with environmental objectives in the context of general equilibrium models could yield useful insights.

The paper by Reed seeks to show why the social dimension of adjustment programs must be integrated into an analysis of the impact of structural reforms on the environment; the author uses two case studies, of Venezuela and El Salvador, to illustrate this. Economic reforms change class structures and social relations in adjusting societies. In the process, such reforms can have negative, long-term environmental impacts. According to the author, these two examples also raise questions about the viability of the World Bank's current win-win strategy, which encourages policymakers to give priority to policy reforms that increase economic efficiency while generating positive environmental changes. The analysis suggests that unless changes in social structures and social relations are examined adequately, apparent win-win situations may actually conceal underlying social contradictions and thereby aggravate already serious environmental problems.

Heerink, Kuyvenhoven, and Qu examine international trade and the environment, with special reference to the agriculture. They indicate that as regards national environmental problems, international harmonization of environmental standards is generally not desirable. Differences in national priorities and in capacities to cope with environmental and natural resource degradation justify variations in environmental standards across countries. Hence, countries should not protect their industries against imports from countries with lower standards. On the other hand, harmonization of the form of environmental policy (principles and measures) is highly desirable. Tensions between trade and the environment may be reduced by global adherence to the "polluter pays" principle (PPP). The cost effectiveness of measures to address international or global environmental problems may differ between countries. The effect of international trade growth on the environment can be positive or negative, depending on the case examined. Six separate effects are distinguished, namely the effects on: (i) allocative efficiency; (ii) scale of economic activity; (iii) transport flows; (iv) output composition; (v) technology; and (vi) environmental policy.

According to these authors, studies of the environmental effects of a worldwide removal of food price distortions indicate that resource use in agriculture will increase in those developing countries that have a commercial farm sector. In addition, land clearance is likely to contribute to deforestation in these countries. On a global scale the increased chemical use in developing countries will be more than offset, however, by lower applications of chemicals that result from production declines in high-income countries. The total level of air, soil, and water contamination by farmers and the average chemical intake by the world's food consumers will decline as a result. Whether higher agricultural prices resulting from trade liberalization will lead to increased soil degradation is a question in dispute. As an effect of price changes, at least four different elements should be distinguished: (i) decisions between current and future production; (ii) changes in farm practices and inputs use; (iii) decisions between production and conservation investments; and (iv) farmers' private discount rates.

In the paper by Torres, environmental issues in the agriculture sector in Latin America are studied. He argues that the solution to the environmental problems of agricultural modernization is neither to reverse the new trends in policies nor to reverse the export orientation of the economies, but to face these problems directly. If most environmental problems originate from some economic distortion (such as externalities or common-property resources), the proper instruments must be used to resolve these distortions at the sectoral or macroeconomic level. The environmental impacts associated with agricultural modernization involve very significant economic aspects, most importantly related to input prices and their indirect impacts on production costs, profitability, and competitiveness. The case studies show that there are market limitations that provide private economic incentives to overexploit natural resources.

The author points out that the behavior of modernized private enterprises toward the environment may vary according to the type and size of the investment project and the country. The ideal enterprise is an institution that coordinates the transformation of inputs (natural resources) into outputs using the best available technology, motivated by the explicit objective of profit maximization. Government policies must then promote conservation of natural resources on behalf of society. The policies should help to internalize the externalities of private firms and involve macroeconomic, sectoral, and social measures. Besides economic policies, there are concrete actions a government may take to deal with environmental problems brought about by market distortions in economic activities. Finally, this paper highlights the potential for win-win strategies that would produce efficient economic growth while minimizing the social cost of natural resource use and environmental degradation in Latin America.

Meier, Munasinghe, and Siyambalapitiya describe a case study that seeks to incorporate potential global environmental constraints into energy sector decisionmaking in Sri Lanka. They show that setting electricity prices to reflect the long-run marginal cost (LRMC) has a significant and unambiguously beneficial impact on the environment (both in-country and globally). The imposition of carbon taxes on fuels used to generate electricity has a more direct impact on greenhouse gas emissions (and other measures related to the use of fossil fuels) than merely adding the equivalent externality cost to the electricity tariff. Pricing policy has a more general impact than physical approaches to demand-side management (DSM). Demand-side management programs are more difficult to implement and limited in scope. Nevertheless, the results suggest that it is hard to justify more expensive measures for greenhouse gas (GHG) emission control, such as wind energy or the substitution of diesels for coal plants, if the more cost-effective measures, such as DSM, transmission and distribution (T&D) loss reduction, and maximum implementation of minihydros, have not been implemented first.

The authors conclude that a number of transportation sector measures, advocated on the grounds of ameliorating local air quality impacts or for general improvements in the fuel efficiency of the sector, prove to have significant GHG emission reduction benefits as well. While some measures to reduce GHG emissions imply a significant increase in other local environmental impacts, these measures also tend to be very expensive and therefore unlikely to be implemented. Pressurized, fluidized bed conversion (PFBC), LRMC pricing, and wind power all reduce GHG emissions and reduce local air quality-related health impacts. GHG emissions reduction options may have a significant impact on system reliability. Wind energy will generally increase system reliability. The maximum hydro scenarios will decrease reliability. This paper clearly and explicitly demonstrates that efficient pricing makes an especially significant contribution to environmentally sustainable development.

Unemo uses a computable general equilibrium (CGE) model to explore the interaction between development strategies and market imperfections in Botswana. The author concludes that if appropriate data are available, CGE models may give some interesting insights, including a more multifaceted picture of the changes taking place in a society as a result of policy changes. Because the purpose of general equilibrium modeling is to show the net effect of different economic forces, the approach may help to remove uncertainties about the outcome of various policies. CGE models may help to derive optimal policies for sound environmental resource use. Furthermore, it is clear that governmental policies and external shocks together with malfunctioning markets can have considerable unintentional impacts on the use of environmental resources. In the present study, this was especially true in the simulation involving a fall in the price of diamonds. This confirms the view that it is important to bring environmental considerations more into economic policymaking.

The author shows two important points to be taken into account when designing structural adjustment programs (or other packages of policy reform). First, it is necessary to analyze how the markets for different goods and resources work (if they exist at all). Second, it is useful to establish what signals the projected policies will create and how these will affect the use of environmental resources. Based on these findings, actions need to be taken to reduce harmful impacts on the environment. The main conclusion is to avoid policies that risk having negative environmental impacts and to choose more environmentally friendly policies. This may, however, be quite difficult because the policies are often designed to address wide economic problems. An alternative remedy is therefore to design and implement complementary measures that will reduce the negative environmental impacts arising from the program. This may, for example, involve measures to establish markets for certain goods and resources that initially are missing or are malfunctioning.

In the final chapter of the volume, Persson and Munasinghe also use a CGE model to examine deforestation in Costa Rica. The results support the conclusions of a more conventional partial equilibrium approach—that establishing property rights tends to decrease deforestation because such rights allow forest users to better capture the future benefits of reduced logging damage today. The CGE results concerning the effects of discount rate changes on deforestation also parallel the predictions of partial equilibrium models—higher interest rates promote deforestation while lower interest rates contribute to conservation.

Beyond confirming the direct results of partial equilibrium analyses, the CGE approach also clearly identifies the indirect effects arising from intersectoral linkages. For example, partial equilibrium analysis predicts that stumpage price increases will act directly to reduce logging. On the other hand, the model shows that while deforestation from logging will indeed decline, total deforestation nevertheless increases. This phenomenon arises from indirect linkages captured by the general equilibrium analysis. The contraction of the logging and forest industry sectors causes a shift of resources toward the much larger agricultural sector. As agriculture expands, deforestation increases. Similarly, if the wages of unskilled labor were increased (for example, because of minimum wage legislation), the model predicts that deforestation could worsen instead of declining. Labor and capital tend to flow from industry to agriculture, leading to the conversion of even more forest land for farming. Finally, both these last two examples underline the importance of pursuing sectoral reforms in parallel with growth-inducing policies.

Conclusion

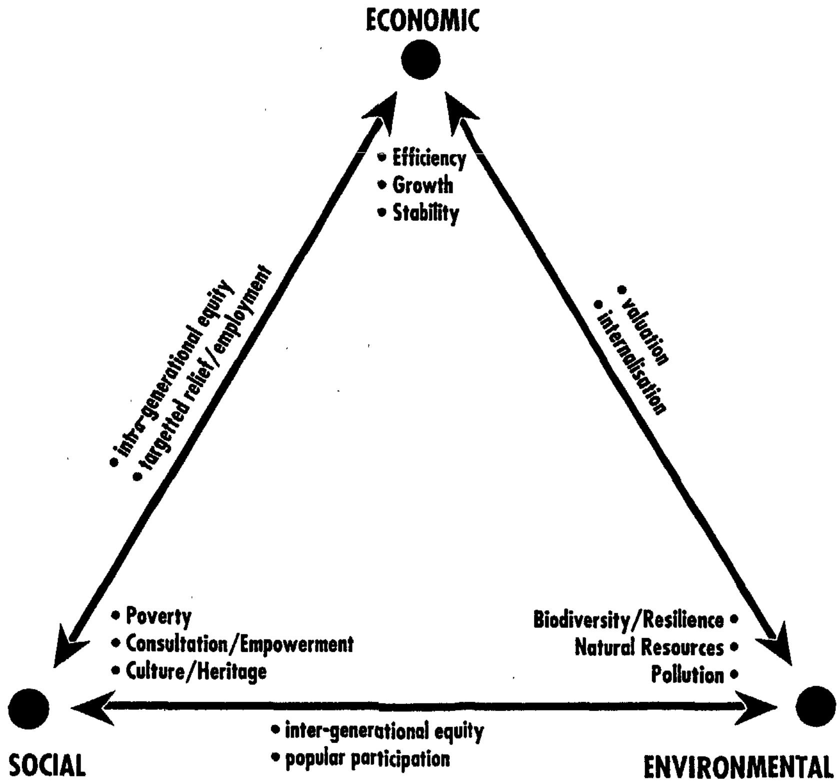
The papers in this volume offer ample evidence that macroeconomic and sectoral policies do have significant environmental (and social) effects. Although tracing such links poses great difficulties, sufficient analytical progress has been made to begin to practically address adverse environmental consequences of economywide policies.

Further applied studies are required to examine links between the longer-run structure of growth, poverty alleviation, and environmental protection. Future work should seek to relate packages of macroeconomic and sectoral policy reforms to a fuller range of priority environmental concerns in a variety of countries. Some areas of current interest such as trade reform and privatization policies deserve early attention. At the same time, emphasis should be placed on developing more practical models and analytical tools that can be applied in a variety of situations.

Distributional, political economy, and institutional issues also ought to be addressed in future work. In this context, greater attention needs to be paid also to the identification, evaluation, and mitigation of the social impacts of economywide policies. The nature of environmental and social problems is heavily dependent on the allocation of political and institutional power, and policy reforms may have substantial implications for the distribution of income and welfare. Thus, there are obvious obstacles to overcoming what might be very powerful vested interests when environmental reforms are recommended. Implementation issues such as asymmetries in the incidence of environmental costs and benefits (especially health impacts), consultation with and empowerment of disadvantaged groups, timing of reforms, and the role of environmental conditionalities will need to be studied.

Finally, the need for a more systematic way of monitoring the environmental implications of reform programs suggests that sectoral and economywide indicators of sustainability should be developed. Recent work that has focused on methods of incorporating environmental aspects into national income accounts needs to be pursued. However, severe data constraints limit the applicability of such a comprehensive approach in many developing countries. Short-cut methods, therefore, ought to be developed. For example, easily applicable rules-of-thumb (calibrated by well-chosen national studies) could be used to devised baseline estimates of national wealth in the form of natural resources, human capital, and produced assets. Selected indicators (both physical and economic value-based) are required to help contribute to the more effective monitoring of economywide conditions of sustainability.

Approaches to Sustainable Development



Source: Munasinghe 1993.

The *economic* approach to sustainability is based on the Hicks-Lindahl concept of the maximum flow of income that could be generated while at least maintaining the stock of assets (or capital) which yield these benefits (Solow 1986, Mäler 1990). There is an underlying concept of optimality and economic efficiency applied to the use of scarce resources. Problems of interpretation arise in identifying the kinds of capital to be maintained (for example, manufactured, natural, and human capital) and their substitutability, as well as in valuing these assets, particularly ecological resources. The issues of uncertainty, irreversibility, and catastrophic collapse pose additional difficulties (Pearce and Turner 1990).

The *social* concept of sustainability is people-oriented, and seeks to maintain the stability of social and cultural systems, including the reduction of destructive conflicts (Munasinghe and McNeely 1995). Equity is an important aspect of this approach. Preservation of cultural diversity and

(Box continues next page)

cultural capital across the globe, and the better use of knowledge concerning sustainable practices embedded in less dominant cultures, are desirable. Modern society would need to encourage and incorporate pluralism and grassroots participation into a more effective decisionmaking framework for socially sustainable development.

The *environmental* view of sustainable development focuses on the stability of biological and physical systems (Munasinghe and Shearer, 1995). Of particular importance is the viability of subsystems that are critical to the global stability of the overall ecosystem. Furthermore, "natural" systems and habitats may be interpreted broadly to also include manmade environments like cities. The emphasis is on preserving the resilience and dynamic ability of such systems to adapt to change, rather than conservation of some "ideal" static state. Natural resource degradation, pollution, and loss of biodiversity reduce system resilience.

Reconciling these various concepts and operationalizing them as a means to achieve sustainable development is a formidable task, since all three elements of sustainable development must be given balanced consideration. The interfaces among the three approaches are also important. Thus, the economic and social elements interact to give rise to issues such as intra-generational equity (income distribution) and targeted relief for the poor. The economic-environmental interface has yielded new ideas on valuation and internalization of environmental impacts. Finally, the social-environmental linkage has led to renewed interest in areas like inter-generational equity (rights of future generations) and popular participation.

In seeking to integrate the three approaches in a practical way, it is useful to recognize that most development decisions continue to be based on the economic efficiency criteria. Thus, it is useful to turn to the relatively new area of environmental economics as a starting point for developing a broader conceptual framework that integrates the economic, sociocultural, and ecological approaches (see Figure 1.1). For example, economists attempt to incorporate environmental concerns into decision making by valuing environmental resources in monetary terms, and ensuring that resource prices reflect their scarcity values. Similarly, economists have addressed social-equity concerns by placing special emphasis on costs and benefits accruing to the poor, by ensuring that those who impose costs on others pay commensurate charges, and more recently, by seeking to protect productive assets for future generations.

The foregoing suggests a broad integrated conceptual approach in which the net benefits of economic activities are maximized, subject to maintaining the stock of productive assets over time, and providing a social safety net to meet the basic needs of the poor. Some analysts support a "strong sustainability" rule which requires the separate preservation of each category of critical asset (for example, manufactured, natural, sociocultural, and human capital), assuming that they are complements rather than substitutes. Other researchers have argued in favor of "weak sustainability," which seeks to maintain the aggregate monetary value of the total stock of assets, assuming a high degree of substitutability among the various asset types. At the same time, the underlying basis of economic valuation, optimization and efficient use of resources may not be easily applied to ecological objectives like protecting biodiversity, or to social goals such as promoting public participation and empowerment—thereby forcing reliance on non-economic indicators of social and environmental status, as well as on other techniques like multicriteria analysis to facilitate tradeoffs among a variety of such non-commensurable objectives.

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The Environmental Impact of Economywide Policies: Some Recent Evidence

Mohan Munasinghe, Wilfrido Cruz, and Jeremy Warford

Recent years have seen a wide range of economywide policy reform programs that have been undertaken to address macroeconomic problems (such as those affecting international trade, government budgets, private investment, wages, and income distribution) and broad sectoral issues (such as those relating to agricultural productivity, industrial protection, and energy use). The economywide mechanisms for attaining these goals include altering the rates of exchange or interest, reducing government budgets, promoting market liberalization, fostering international openness, enhancing the role of the private sector, and strengthening government and market institutions, often coupled with pricing and other reforms within key sectors such as industry, agriculture, and energy.

Although these policies are typically not directed explicitly toward influencing the quality of the natural environment, they may, nonetheless, have major impacts, either positive or negative, on it. This chapter argues that there are significant payoffs in attempting to understand such impacts better and to act on them. Positive impacts of economywide reforms on the environment can be used to build constituencies for reform. Potential negative impacts need to be analyzed, monitored, *and* mitigated. In some instances, the direction of environmental impact stemming from economywide policy reform is fairly straightforward. The extent of the impact, however, invariably requires empirical analysis. In more complex cases, even the direction of the impact is ambiguous. In view of their location-specific nature and the complexity of economic, physical, ecological, institutional, and cultural variables involved, more case study material is clearly needed to enhance our understanding of these relationships.

The case studies used to illustrate the main conclusions of this work were carried out within the World Bank over the last several years. They reflect a wide range of country situations and environmental problems. Pollution issues are addressed with reference to air quality in Mexico, industrial pollution caused by specific industries in Indonesia, and general industrial pollution in Poland. Environmental aspects of energy use are addressed in the Sri Lanka case. Various issues related to natural resources are covered in the other studies: deforestation and land degradation in Costa Rica, deforestation in the Philippines, degradation of agricultural lands due to overgrazing in Tunisia, fertility losses due to extension of cultivated areas in Ghana, water resource depletion in Morocco, unsustainable agriculture in China, and wildlife management in Zimbabwe.[2]

The case studies also use a variety of analytical methods to illustrate the different approaches available for identifying the environmental implications of economywide reforms. These methods range from directly observing the links between economic incentives and resource use to relying on complex economic modeling of policies and their environmental effects. In all the studies, however, the analytical approach uniformly requires identifying key environmental concerns and relating these to the agenda of high-priority sectoral and macroeconomic reforms under consideration. The analysis underscores the formidable difficulties involved in developing a general methodology to trace all possible environmental impacts of a package of adjustment reforms, and until recently there has been relatively limited empirical work on this subject (exceptions include Cruz and Repetto 1992; Mahar 1988; Panayotou and Sussangkarn 1991; Reed 1992). Nonetheless, the case studies offer evidence that careful case-specific empirical work may help to identify better ways to deal with potentially serious impacts of specific economywide policies on high-priority environmental problems. This chapter also indicates the considerable scope that exists for developing better analytical tools to trace the linkages between environmental and economic policy.

Linkages between the environment and economywide policies

This chapter focuses on the environmental implications of economywide policy reforms undertaken at the sectoral or macroeconomic level. Although the emphasis is on economic policies, other noneconomic measures are also relevant, such as social, institutional, and legal actions. A recurring theme in the case studies is that the potential for achieving parallel gains in conventional economic, social, and environmental goals is often present whenever economywide reforms attempt to improve macroeconomic stability, increase efficiency, and alleviate poverty. However, in important cases, these potential gains cannot be realized unless complementary environmental and social measures are carried out.

The specific findings are grouped according to the principal ways in which economywide policies may interact with the environment:

- First, many economic reforms initiated to promote more efficient resource allocation and use are also environmentally beneficial. However, residual imperfections often give rise to environmental harm.

- Second, stabilization measures meant to restore macroeconomic stability are necessary for sustainable development, but short-term contractionary aspects of such programs also may have adverse environmental implications.
- Finally, economywide policies have longer term implications on economic growth and income distribution, that may also lead to environmental changes.

In the ensuing sections, these broad findings are illustrated, first, by specific World Bank country studies and, second, through other selected studies. Due to space limitations, it was not possible to have a more comprehensive literature review.

Efficiency-Oriented Reforms

CONSOLIDATING ENVIRONMENTAL GAINS

Economic liberalization programs which address price-related distortions ("getting prices right") can contribute to both economic and environmental goals, by promoting efficiency and reducing waste.

In many developing countries, misplaced efforts to promote specific regional or sectoral growth and general economic development have created complex webs of commodity, sectoral, and macroeconomic price distortions, resulting in economic inefficiency and stagnation. Often, these economic distortions also lead to unanticipated changes in production and input-use that promote resource overexploitation or pollution. Such economic distortions may arise from a macroeconomic policy (such as the overvaluation of the local currency) or from a sectoral policy with economywide implications (such as subsidized energy prices).

In either case, economywide policies that correct such price-related distortions will also result in environmental gains. Among the broadest are macro-remedies to correct the foreign exchange rate and taxes that distort trade. More sector-specific reforms seek to shift key relative prices—for example, setting efficient prices for energy or water (which have pervasive effects), and removing taxes or subsidies on particular commodities or factors of production.

The environmental benefits of macroeconomic reforms were observed in Zimbabwe (Muir-Leresche and Bono 1994). From an environmental perspective, wildlife-based economic activities (including ecotourism, safaris, hunting, and specialized meat and hide production) are better suited to that country's semi-arid climate and poor soils than cattle ranching which competes for the same limited land resources). The former also constitute some of the fastest growing sectors—wildlife-based tourism alone grew at the rate of 13 percent in 1991, comprising 5 percent of the gross domestic product (GDP). Despite its economic and environmental advantages, sectoral land policies have generally discouraged wildlife activities since these are perceived as "underutilizing" land. Livestock marketing and price policies have traditionally subsidized cattle ranching.

More importantly, for many years, the government's foreign exchange and trade policies indirectly penalized the wildlife sector. The Zimbabwean dollar was overvalued by 50 to 80 percent from 1981 to 1990. This meant that export-oriented sectors were implicitly taxed, among them wildlife and nature tourism concerns. Foreign exchange earnings were diverted to other sectors, depressing incomes and investment in wildlife. In the early 1990s, the government introduced an adjustment package, including measures aimed at boosting the level of exports. The currency was devalued by 25 percent, and more liberal access to foreign exchange was allowed. These moves were beneficial on both economic and ecological fronts. Although the economy still has a long way to go, exports have improved. At the same time, the profitability of the wildlife sector increased, leading to an expansion of land allocated to wildlife—which is also environmentally more desirable.

The environmental implications of sectoral reforms in energy pricing and rangeland management were studied in Sri Lanka and Tunisia, respectively. The Sri Lanka study demonstrates that energy sector reforms can contribute to both economic and environmental goals (Meier, Munasinghe, and Siyambalapitiya, Chapter 8 of this volume). As in most developing countries, electricity prices in Sri Lanka have been well below the incremental cost of future supplies. Many studies show that eliminating power subsidies by raising tariffs closer to the LRMC of power generation, will encourage more efficient use of electricity.

In projecting future electricity requirements, the study found that the economic benefits of setting electricity prices to reflect LRMC is supplemented by an unambiguously favorable impact on the environment (including local air quality, biodiversity loss and greenhouse gas emissions). In addition, pricing reforms were found to have better economic and environmental impacts than purely technical approaches to demand-side management, such as promoting the use of energy-saving fluorescent lights.

The negative effects of underpricing resources in the agricultural sector is illustrated in the Tunisia study (Partow and Mink 1995). The government's concern with ensuring sufficient supply and affordability of livestock products in Tunisia has resulted in a web of pricing and subsidy interventions. A variety of subsidies has promoted livestock production intensification in certain parts of Tunisia, while in other regions they have encouraged herd maintenance at levels beyond rangelands' carrying capacity. Particularly during dry years, subsidized feed imports have substituted for natural pasture, and have averted herd contraction. This failure of herds to respond to diminished feed availability in natural pastures, however, has contributed to significant rangeland degradation primarily in the central and southern regions of the country. Reversing such environmental damage will require policy reforms relating especially to subsidies to the livestock sector.

Other Studies: A recent World Bank study suggests that trade policies which encourage greater openness in Latin America have tended to be associated with a better environment, primarily due to environmentally benign characteristics of modern technologies (Birdsall and Wheeler 1992). The nature of the environmental impacts of adjustment reforms (like the exchange rate changes and trade liberalization examples above), have been questioned for some time. The broader issues raised by links between trade and environment are summarized in Box 2.1.

In Zambia, foreign exchange reforms have had a positive impact on wildlife populations, particularly of large mammals—by reducing the incentives for illegal trophy hunting to obtain scarce foreign currency (Mupimpila et al. 1994). In Tanzania, a case study of structural adjustment policies and the impact on the environment, suggests that exchange-rate adjustment could provide greater incentives to protect national parks, game reserves and nature conservation areas. In Vietnam, a computable general equilibrium (CGE) model simulation of forest policy reforms indicates a significant increase in forest area and the creation of 24,000 new jobs, as well as benefits from avoided loses in terms of land degradation and loss of property and lives due to flooding.

Box 2.1 Trade and the Environment

As noted in the *World Development Report 1992: Development and the Environment*, the concern with environmental implications of trade involves both the domestic implications of policy reforms as well as the global environmental dimension of international trade agreements. Although liberalizing reforms generally promote more efficient resource use (including use of environmental resources), in practice there is no clear-cut reason to expect that trade liberalization will be either good or bad for the environment. The reason is that trade reforms may be undertaken, but the presence of pre-existing market, policy, or institutional imperfections in the environment sector may lead to adverse environmental impacts. The following discussion illustrates various environmental initiatives that will be needed to complement reforms in the trade sector.

Regarding national or domestic trade reforms, early concerns about negative effects were raised regarding the North American Free Trade Agreement (NAFTA) and pollution in Mexico. Similar concerns involved cassava exports and soil erosion in Thailand, and exchange rate depreciation and deforestation in Ghana. However, more recently there has been increased recognition that the links between trade and the environment are much more complex since economic expansion from trade is characterized not only by growth but also by changes in the intersectoral composition of output, in production techniques and input-use, and in location of economic activity.

For example, if liberalized trade fosters greater efficiency and higher productivity, it may also reduce pollution intensity by encouraging the growth of less polluting industries and the adoption of cleaner technologies. In Mexico, Grossman and Krueger (1991) conclude that increased specialization due to NAFTA-related trade liberalization would result in a shift to labor-intensive and agricultural activities that require less energy inputs and generate less hazardous waste per unit of output than more capital-intensive activities. Similarly, in the Indonesia case study (cited in the text), both pollution- and energy-intensity declined due to such shifts. Pollution impacts probably declined as well, due to the dispersion of industry away from Java. However, the rapid growth of the industrial sector in recent years has also meant an increase in total pollution in spite of reduced pollution intensities. As more countries succeed in attaining rapid and sustained growth, there will be an increasing need to more carefully examine the relationship between the changing structure of high growth economies and the danger of excessive pollution. In such cases, the pollution problem may need to be addressed aggressively, with a combination of regulations and economic incentives.

On agriculture and forestry, contrary to popular perceptions, a shift in cropping patterns toward export crops expansion does not necessarily imply increased erosion. Repetto (1989), using examples for Sub-Saharan Africa, concludes that many export crops tend to be less harmful to soils. In West Africa, tree and bush crops are grown with grasses, and erosion rates are two to three times less than similar areas planted for locally used food crops such as cassava, yams, maize, sorghum, and millet. In Malawi, Cromwell and Winpenny (1991) found that adjustment led to changes in product mix and production intensity instead of changes in cultivated area or production techniques. Soil-improving crops were adopted and agricultural intensification helped absorb a rapidly growing population on less land. Also, contrary to popular belief, export crop expansion has not generally occurred at the cost of reduced food crop output, with subsequent potentially negative social and environmental effects. However, in a study of eleven developing countries, it was found that rapid expansion of cash crops, in fact, does not tend to reduce food production. This complementarity rather than competition has been observed in countries where initial productivity is low and is partly explained by technology spillovers from cash crop activities that also enhance food crop production.

The more pressing question is whether these export crops displace forests. In Sudan, Stryker and others. (1989) found that trade and other adjustment-related reforms resulted in significant deforestation because increased producer prices encouraged woodland clearing for crop cultivation. However, recent studies have shown that in such cases, deforestation pressures are due to prevailing distortions within the forestry sector, such as very low stumpage prices or poor forest management capacity that are not corrected with the trade reforms. Inadequate land tenure and land clearing, as a requirement for tenure, prevent more efficient exploitation of existing agricultural lands, and have also contributed to the problem. For example, in Côte d'Ivoire, the effects of price-related policies were believed to have led to deforestation, but to a lesser extent than the lack of a consistent and secure land tenure system (Reed 1992). The Ghana study (cited in the main text) also analyzed the interaction between effects of price changes and the institutional factors governing resource ownership and management. Using both household data and remote sensing information on agricultural and forest resources, the study found that increased crop incentives have contributed to pressures for deforestation. However, if producers had secure tenure and could internalize the implications of excessive land exploitation, these pressures would have been reduced significantly.

With regard to the global environmental dimension of international trade, the debate has

(Box continues next page)

revolved around the issue of whether freer trade is beneficial to global and national environmental conditions and whether it should be used to influence national and internatinal environmental standards and agreements. Studies arising from a recent General Agreement on Tariffs and Trade (GATT) symposium have concluded that expanding global production and consumption does not necessarily cause greater environmental degradation (Anderson and Blackhurst 1992). Indeed, with appropriate national policy reforms, greater trade would generally contribute to environmental gains. In the case of coal, trade liberalization and the removal of price supports in richer countries would reduce coal output, lead to higher international prices, and consequently decrease coal consumption. This would be beneficial for the environment. In the case of food production, the reduction of agricultural trade protection in rich countries would lead to a relocation of production to poorer countries, leading to greater incomes, and reduced agricultural pollution in developed countries. In poorer countries, it is recognized that the incentive to produce more will probably increase fertilizer and pesticide use. However, maintaining high levels of agricultural protection in rich countries is not an effective way of protecting the environment.

Domestic tax incentives and regulations would be a better way of limiting environmental degradation (Anderson and Blackhurst 1992; Lutz 1993). The same general conclusion is reached in recent studies on biodiversity and forestry. For example, the over-exploitation of biodiversity and wildlife for international trade plays a minor role in species extinction since the major cause is habitat destruction (Burgess 1991). Thus, attempts to ban wildlife trade will have limited benefit plus large cost; proper trade mechanisms such as taxes and subsidies would be better at encouraging conservation.

With respect to global deforestation, Barbier et al. (1991) found that the timber trade has not been the major source of deforestation. The domestic factors (distorted prices, subsidies, tax regimes, regulations, management capacity) leading to conversion of forest land to agriculture has played the larger role. In general, an appropriate combination of domestic environmental and agricultural policy measures, combined with trade reforms, will result in both welfare gains and in better environmental quality (Harold and Runge 1993). On the international front, however, the challenge is to initiate coordinated international action on domestic reform measures to counter the environmentally negative effects of scale—any country attempting to implement domestic reforms in isolation will lose income and jobs to its neighbors.

An early view on the effect of freer trade given different national environmental standards between North and South, was that dirty industries would migrate to poor countries, where environmental standards were either less strict or non-existent (Leonard 1989). Recent work indicates that pollution abatement and control expenditures by firms do not appear to have had a significant effect on competitiveness in most industries since these expenditures represent a modest share of total costs. For example, environmental costs generally comprise only 0.5 percent of the value of output and only 3 percent for the most polluting industry (Low 1992). Thus, environmental costs are not a dominating factor in decisions for locating new industrial investments. In fact, trade openness which may promote newer technologies may tend to have positive environmental effects since most new technologies are also cleaner (Birdsall and Wheeler 1992).

These findings also suggest that there is no pressing reason for requiring national environmental standards to be made identical. Patterns of resource exploitation and pollution are primarily affected by economic and social conditions, with environmental regulations or standards (especially in poor countries) playing a minor role. Promoting acceptance of similar environmental principles, such as requiring that polluters pay for the damage they inflict, or incorporating environmental values in cost-benefit analysis, will probably be more effective as well as politically more acceptable.

Further work in this field should include efforts to establish more clearly: (a) the environmental implications of liberalized trade flows; (b) the extent to which pollution from industrial growth may undermine declining pollution intensity effects from trade reforms; and (c) whether trade measures should be resorted to as "second best" policies when international coordination fails to remove domestic distortions (for example, green labeling in the timber trade when the timber resource is underpriced in exporting countries).

AVOIDING ENVIRONMENTAL HARM

While liberalizing policies typically help both the economy and the environment, other unaddressed policy, market and institutional imperfections may cause environmental harm, unless they are addressed through specific additional measures that complement the broader reform programs.

The reform process is typically undertaken in stages, with the initial adjustment package aimed at the most important macroeconomic issues. Existing distortions that policymakers intend to address later in the adjustment process, or other constraints that have been overlooked, may cause environmental harm. Paralleling the way in which the social consequences of adjustment should be handled, such potential adverse environmental consequences due to remaining inefficiencies or inequities in the economic system may, therefore, require additional measures to be introduced – to complement the original reform program.

Policy distortions. In Morocco, low water charges constitute a prevailing policy distortion that have artificially promoted production of water intensive crops, such as sugar cane. Thus, rural irrigation water accounts for 92 percent of the country's marketed water use, while charges cover less than 10 percent of the long-run marginal cost of irrigation (Goldin and Roland-Host 1993). Going beyond the traditional sectoral remedy of proposing an increase in water tariffs, the study employed a computable general equilibrium (CGE) model to link sectoral policy reforms with the macroeconomic adjustment program, focusing on trade liberalization.

In the CGE simulation, removal of nominal trade tariffs led to a small rise in real GDP. Household incomes and consumption grew as import barriers were reduced, exports became more competitive, domestic purchasing power rose, and resources were allocated more efficiently across the economy. However, environmental implications were negative, as domestic water use increased substantially due to the expansionary effects of liberalization. To remedy the environmental harm water price increases need to be combined with trade liberalization, so that the beneficial expansionary economic effects of the latter may be largely retained, but now with substantial reductions in water use as well.

Market failures. Aside from existing policy distortions, the absence of price signals for environmental services can undermine the contribution of efficiency- and growth-promoting reforms. The specific role of *market failure* in influencing the environmental implications of economic reforms is illustrated in the case of liberalization policies and industrial promotion in Indonesia (Wheeler and Martin, forthcoming). In this case, adjustment reforms which are successful in the traditional sense of stimulating industrial growth may have adverse pollution consequences because of market failure –no price signals prevent excessive build-up of pollution.

The study identifies growth patterns which can help control pollution problems. In terms of emissions per unit of output, or pollution intensity, the study found that processing industries (for example, food products, pulp and paper) tend to be dirtier than assembly (for example, garments, furniture) industries. Liberalization in the 1980s promoted a surge in assembly industries, thereby reversing the 1970's pattern of more rapid growth in "dirty" processing sectors. Projections indicate that the share of basic processing industries in total industrial output will fall from 72 percent in 1993 to about 60 percent by 2020.

In addition, industry expanded rapidly outside densely populated Java, reducing the health impact of industrial concentration. However, industrial output growth has been so rapid that general pollution levels have nevertheless increased. Thus, while decreases in pollution intensity and industrial decentralization have helped to limit pollution, formal regulations will need to be strengthened also, to avoid health and environmental damage in the future.

Institutional constraints. The nature of macroeconomic effects on the environment is also contingent upon prevailing regulations or institutions governing resource use. Thus, *institutional constraints* that are pervasive may undermine the potential contribution of policy reforms. For example, the eventual impact of economywide reforms (such as those affecting international and domestic terms of trade) on the incentives facing farm households will be influenced by intervening institutional factors, especially those affecting access and use rights over agricultural resources such as land and water.

The role of institutional constraints in macroeconomic reform programs is examined in the Ghana case study (Lopez, forthcoming). In this example, trade liberalization, by reducing the taxation of agricultural exports leads to increased production incentives, while efforts to reduce the government wage bill tend to increase the pool of unemployed. Thus, the adjustment process helps to stimulate production of export crops, and combines with rapid population growth and lack of employment opportunities outside the rural sector to create increasing pressure on land resources, encroachment onto marginal lands, and soil erosion. This effect on resource use is influenced by the allocation of property rights. Whether in relation to the security of land tenure of peasant farmers, or to the right to extract timber by logging companies, uncertainty normally results in environmental degradation. In Ghana, as in many regions of Africa, agricultural lands are governed by traditional land use institutions, and farms are communally owned by the village or tribe. These common property regimes may have been sufficient in allowing sustainable use of agricultural lands when populations were much smaller, and sufficient fallow periods could allow land to regain its fertility. However, such traditional arrangements would be overwhelmed ultimately by economywide forces, resulting in reduced fallowing, loss of soil fertility and environmental decline.

Another common institutional problem relates not to the rules and regulations themselves, but rather to the government's capacity to establish and enforce such rules. Regulating large numbers of potentially environmentally degrading activities is especially difficult, even for industrialized country governments. Substantial reductions in institutional and monitoring needs may be achieved with the use of indirect measures or modified pricing-regulation approaches. This is illustrated by the Mexico City air pollution study which shows that while, in principle, pollution taxes are the most accurate means of achieving reductions in pollutants, in practice, administrative feasibility demands that less refined instruments such as taxes on consumption of fuels may have to be used (Eskeland and Ten-Kate, forthcoming). While recourse to blunt instruments will help, the magnitude of the institutional capacity-building challenge nevertheless remains clear. Building the relevant institutional capacity in developing countries therefore should be underscored, and appropriate resources should be made available early in the adjustment process to assist country governments in this task.

A study of energy prices in Poland concludes that energy intensity and excessive pollution in Poland is due not only to the undervaluation of coal in the centralized price system but more importantly, to institutional problems rooted in state ownership that encourages output maximization rather than cost minimization (Bates et al. 1994). This means that price responsiveness is blunted, since financial losses are simply absorbed by the public budget, or passed on to consumers in the form of higher output prices. Thus, energy sector restructuring efforts have recognized the need to create a new institutional and legal framework that will facilitate competition and greater private sector participation. Coupled with aggressive energy pricing reforms, this strategy appears to be making some headway.

Other studies: The need for *complementary environmental reforms* is illustrated also in the case of forestry in Tanzania, where specific reforms in forest sector pricing and regulation are needed to ensure that the incentives from currency devaluation and trade liberalization do not lead to increased timber exports and unsustainable forest exploitation (Bagachwa et al. 1994). Similarly, in Jamaica, an on-going study shows how foreign exchange reforms have increased the revenue generated by the tourism sector (Alleyne et al. 1994). However, the increasing pressure of associated economic activity has caused considerable degradation of natural habitats and increased urban pollution – thus calling for complementary environmental protection measures.

Macroeconomic stabilization measures

CONSOLIDATING ENVIRONMENTAL GAINS

Measures aimed at restoring macroeconomic stability will generally yield environmental benefits since instability undermines sustainable resource use.

The relationship between environmental issues and policy reforms is fairly straightforward at a general level. Macroeconomic instability is not only disastrous for the economy, but also frequently detrimental to the environment. For example, high interest rates associated with economic crises can severely undermine incentives for sustainable management of resources, as producers seek to maximize current yields at the expense of future output.

Box 2-2. Debt and the environment

One of the early antecedents of the concern about the relationship between economywide policies and the environment was the debt and degradation link noted by the Brundtland Report (1987): *debt that cannot be amortized forces raw material-dependent countries in Africa to deplete their fragile soils, with the result that good land is turned into desert.* The perception was that many countries reacted to the external shocks during the economic crisis years of the early 1980s by exploiting natural resources unsustainably. However, evidence from country case studies and from cross-country statistical exercises does not support this view.

For example, a World Wildlife Fund report, based on case studies for Cote d'Ivoire, Mexico, and Thailand, concluded that there is no simple relationship between external debt levels and environmental degradation. In the case of Cote d'Ivoire the research team found that although the country's deforestation rate was one of the highest in the world, external debt did not affect environmental degradation in general or the forestry sector in particular (Reed 1992). In another study, using econometric models with cross-country deforestation data, no consistent statistical relationship was found between debt and forest depletion (Capistrano and Kiker 1990).

In fact, many factors are at work, and primary commodities such as timber exports do not exhibit any simple trend during the debt crisis and adjustment periods. For example, in the early 1980s, primary commodity exports were subject to falling international commodity prices. Thus, production, domestic absorption, and price effects need to be assessed for specific commodities and countries (Reisen and Van Trotsenburg 1988). Indeed, since the debt crisis was associated with falling export prices and domestic economic contraction for many developing countries, it would not be unreasonable to expect that in some countries the rate of resource extraction, instead of increasing, would have actually declined during this period.

Ideally, countries go into debt with the expectation that the benefits from the productive activities to be funded will more than pay for the loan. In practice, debt often is incurred to support balance of payments deficits. In the environmental context, debt-for-nature projects represent an effort to directly channel debt (or in this case its converse, debt-relief) to beneficial environmental activities. Such debt-relief efforts have enabled environmental organizations to leverage their available funds significantly (World Bank, 1994e). In countries such as Costa Rica, debt-relief programs have allowed environmental agencies to fund forest or biodiversity protection initiatives.

Thus, to the extent that policy reforms can help restore macroeconomic stability, their impact will be unambiguously beneficial for long-term natural resource management and environmental concerns. This link is illustrated in the Costa Rica case study, which used a macroeconomic model incorporating timber harvesting activities, to examine the deforestation implications of various macroeconomic factors (Persson and Munasinghe 1995). Simulation results demonstrate that lower interest rates associated with a stable economy allow the logging sector to correctly anticipate benefits from future returns to forestry, thereby leading to a decline in current logging activities.[2] In Brazil, a recent Bank study found that if interest rates are very high farmers would choose farming practices that have initially high returns but led to significant subsequent declines in productivity (Schneider 1994). Thus, to the extent that adjustment policies can help restore macroeconomic stability, their impact will be unambiguously beneficial for long-term natural resource management and environmental concerns.

The issue of high debt levels (often associated with sustained periods of government budget deficits and macroeconomic instability) and its implications for environmental degradation were also raised some time ago. However, the available evidence indicates that the linkage is neither clear-cut nor significant, as summarized in Box 2-2.

Avoiding Environmental Harm

While restoring economic stability is needed for sustainable development, specific measures to promote stabilization may have unforeseen adverse impacts on the environment, and compensating environmental measures will be needed.

To the extent that economywide policy reforms promote new economic opportunities and employment, in the long-term they will clearly alleviate poverty and reduce pressures that encourage unsustainable exploitation of fragile resources by the unemployed. However, in the transition period when fiscal austerity is required to arrest deteriorating economic conditions, short-term distributional problems may arise, linked to the recessionary aspects of reforms.

The apprehension over short-term environmental impacts of adjustment-related reforms, parallel concerns regarding the social impacts of adjustment. With austerity measures, it was feared that the poor, who would be most vulnerable to the effects of macroeconomic contraction, would also be adversely affected, as social services were cut. Indirectly, short-term negative effects on poverty may have environmental implications (see Box 2-3). However, the main source of concern regarding environmental impacts was that government budgetary restrictions might disproportionately affect environmental protection programs.

In a study by ECLAC (1989), it was concluded that adjustment policies pursued in Latin America during the 1980s led to cutbacks in current expenditure allotments for managing and supervising investment in sectors such as energy, irrigation, infrastructure and mining. This limited the funds available for environmental impact assessments and the supervision of projects to control their environmental impacts. Miranda and Muzondo (1991), in an IMF survey, recognized this problem and suggested that high levels of government expenditure in other areas may lead to reduced funding of environmental activities (Reed 1992). Recent case studies attributed increases in air pollution problems in Thailand and Mexico to reductions in expenditures for adequate infrastructure (Stryker et al. 1991).

While the argument sounds reasonable enough that government cutbacks undertaken as part of adjustment austerity efforts may undermine the funding for environmental initiatives, empirical assessment of its true importance is difficult. Usually, only general categories of expenditures can be identified in most government budgets, so that detailed assessments of environ-

Box 2-3. Poverty and the Environment

It is no accident that assessments of the impacts of pollution invariably bring up concerns about poverty. In many cases, the worst effects of environmental pollution and resource degradation are borne by the poor, especially in terms of health problems and reduced productivity. In both urban and rural areas and in various occupations, they are the ones who can least afford to protect themselves from environmental degradation: the poor spend long hours in polluted factories; they are exposed to agricultural chemicals; and services, such as clean water and trash disposal which are usually taken for granted by those who are better off, are normally unavailable in slums and rural areas.

Environmental degradation is also systematically linked to the problem of access to productive resources. The rural poor and landless workers often depend on the exploitation of fragile, open access resources to supplement their meager livelihood. For example, agricultural plantation workers may depend on seasonal fishing or slash-and-burn agriculture for subsistence. In addition, if poverty and unemployment are pervasive the poor may be forced to migrate to environmentally vulnerable areas, such as hilly lands or coastal fisheries, where there is open access.

Such open access conditions in the face of increasing population and unemployment result in over-exploitation. The situation in many coastal fisheries illustrates this problem of the "tragedy of the commons." As long as there is a surplus to be gained from fishing, more households will migrate to the fishery, until eventually output declines and everyone is relegated to equally poor levels of subsistence. Population pressure on hilly lands lead to similar results for shifting cultivators. In both cases, the landless poor are driven to over-exploit open access resources and, in the process, degrade their source of livelihood In brief, the very poor, struggling at subsistence levels of consumption and preoccupied with day-to-day survival, have limited scope to plan ahead and make natural resource investments (for example, soil conservation) that give positive returns only after a number of years. Such short time horizons are not innate characteristics, but rather the outcome of policy, institutional, and social failures. The poor's use of natural resources is also affected by their facing greater risks, with fewer means to cope. These risks range from misguided policy interventions in input and output markets to changing land tenure systems that favor those with greater political clout. This means that the poor will have little choice but to over-exploit any available natural resources.

How can policy reforms help alleviate the problem? From an individual decision-making perspective, policies that alter relative prices will affect current production and consumption activities of farming households as well as their future use of available resources. Thus, price policy reforms could promote environmentally benign crops and farming practices or discourage excessive water or pesticide use. Land improvement and soil conservation could also be encouraged if increased income and welfare allowed farmers to invest more in land and water management. Clearly, this "resource endowment" effect due to the increased valuation of the household's resources would be sensitive to whether or not access to such resources is secured, for example, through well defined land tenure arrangements.

Beyond the microeconomic aspects of poverty oriented reforms, broad sectoral price changes and macroeconomic prices that alter factor flows and change the structure of the economy will also affect conditions of poverty and the environment. Thus, to the extent that economywide policy distortions have contributed to population pressure on fragile resources, adjustment-related reforms should also help. Import-substitution, industrial protection, and regressive taxation are some policies that have historically been associated with lagging employment generation, income inequality, and poverty There reforms, such as those that promote export growth will lead to higher incomes for sectors producing exportable crops and manufactured goods, generally reducing poverty among rural and industrial workers. Better economic conditions in agriculture and industry would also reduce the problem of frontier migration that has been associated with agricultural extensification. Because of their economywide impacts, the potential contribution of such policies to alleviating poverty and reducing environmental degradation could be substantial.

mental programs usually cannot be initiated. In one effort that was undertaken to assess the social consequences of adjustment lending in Africa, it was found that although there have been declines in government expenditures, the budget proportion going to social expenditures and agriculture actually increased during the adjustment period (World Bank 1994b).

The results of studies focusing on social safety nets during adjustment programs confirm that pursuing fiscal discipline and macroeconomic stability need not take place at the cost of increased hardship for the poor. In much the same way, specific environmental programs could be protected when stabilization efforts are being pursued. For example, it has been reported that in many countries in Sub-Saharan Africa, forestry departments and their activities have always been severely underfunded (Stryker et al 1989). Thus, targeted efforts to support forestry management activities could, with modest costs, be included in reform packages as part of a proactive environmental response.

In Cameroon (Tchoungui et al. 1994), government retrenchment measures eliminated a successful village extension programs (thereby causing a major setback in rural development), and also cut back on forest services, (affecting the monitoring of logging and collecting of stumpage fees.) Similarly, in Zambia, because of adjustment-related budget cutbacks, urban water pollution problems have become worsened, in part due to the shrinking budget of the Water Affairs Department (Mupimpila et al. 1994). Indirect, recessionary effects are being studied in Tanzania, where the government has sought to control inflation by restricting money supply, and also abolished government controlled rural co-operatives (Bagachwa et al. 1994). The impact of these policies has reduced rural farmers' access to credit, and the overall economic and environmental impacts are likely to be negative – due to an increase in deterioration of irrigation networks and depletion of soil fertility, as well as greater pressure to clear new land.

Long-Term Poverty and Income Effects

In addition to the short-to medium term concerns discussed earlier, economywide policies will have significant longer-term environmental impacts – both positive and negative.

The crucial long-term links between poverty and environmental degradation in developing countries are increasingly being recognized (see Dasgupta and Maler 1991). For example, the *World Development Report 1992* noted that the growing evidence of the relationship between reducing poverty and addressing environmental goals points to the need to undertake poverty and population programs as part of environmental efforts (World Bank 1992a). The need to break the "cycle" of poverty, population growth, and environmental degradation has also been identified in a recent report of the International Development Association as a key challenge for sustainable development (IDA 1992).

An important result of examining the general equilibrium effects of macroeconomic policy is that indirect resource allocation effects are important and may dominate the more direct effects of some price or income policy changes. In the Costa Rica study, the economic and environmental implications of wage restraints in structural adjustment are examined with the use of a computable general equilibrium (CGE) model which highlights the economic activities and factors affecting deforestation in Costa Rica (Persson and Munasinghe 1995). The model differs from standard approaches in two important respects. First, it can simulate the effect of introducing property rights on forest resources, thus allowing the private valuation of future forestry returns to contribute to sustainable management. Second, it also includes markets for logs and cleared land–loggers deforest to sell timber to the forest industry and squatters clear land for agricultural production and for sale to the agriculture sector (as the latter expands and requires more land).

The importance of indirect effects in Costa Rica is demonstrated in the analysis of economywide policy changes, such as an increase in the wage rate. Because the role of inter-sectoral resource flows is incorporated in the CGE model, the effects of changes in wages are different from partial equilibrium results. If the wage of unskilled labor were increased due to, say, minimum wage legislation, the model predicts that deforestation could worsen rather than decline. Although logging declines due to increased direct costs, this is more than made up by the indirect effect of intersectoral flows since the industrial sector (where minimum wage legislation is more binding) is much more adversely affected by the higher labor costs. Labor and capital thus tend to flow from industry to agriculture, leading to greater conversion of forest land for farming.

This simulation exercise suggests the need for caution in attempting to "legislate" income improvements by increasing minimum wages. Introducing higher wages initially improves labor incomes but a resulting contraction of industrial and agricultural employment leads not only to more unemployment but to environmental degradation as well. The increase in unemployment results in greater pressures for expanding shifting cultivation in forest lands.

Beyond pricing and inter-sectoral environmental linkages that can be identified in general equilibrium approaches, policies addressing rural poverty and unemployment would also affect the environment. This link occurs within the broader context of the social and demographic problems of inequitable land access and rapid population growth (Feder et al 1988; Cruz and Gibbs 1990; Lele and Stone 1989). Import substitution, industrial protection, and regressive taxation are some economywide policies that have historically been associated with lagging employment generation, income inequality, and poverty. Unequal distribution of resources and inappropriate tenure are institutional factors that also contribute to the problem. In the context of inequitable assignment of endowments and rapid population growth, the resulting unemployment and income inequality force the poor to depend increasingly on marginal resources for their livelihood. The result is pressure on fragile environments. This effect can be analyzed in conjunction with the assessment of large migration episodes. These may occur as part of direct resettlement programs or may be induced by inappropriate policies, such as land colonization programs.

With regard to sustainable agriculture concerns, the study of the *Population, Environment and Agriculture Nexus in Sub-Saharan Africa* explicitly links the related problems of rapid population growth, agricultural stagnation and land degradation in Africa (Cleaver and Schreiber 1991). The study found that shifting cultivation and grazing in the context of limited capital and technical change cannot cope with rapid population growth. At the same time, the traditional technological solution of relying on high yielding crop varieties is not available. Thus, the study identified the need for a mix of responses in terms of reforms to remove subsidies for inappropriate land uses, improve land use planning, recognize property rights, provide better education, and construct appropriate rural infrastructure to promote production incentives.

Regarding economywide factors affecting deforestation, the Philippines case study evaluates the policy determinants of long-term changes in rural poverty and unemployment that have motivated increasing lowland to upland migration (Cruz and Francisco, forthcoming). This process has led to the conversion of forest lands to unsustainable agriculture and has been identified as a key mechanism contributing to the deforestation problem. The inability of the government to manage forest resources is an important direct cause of deforestation, but there is increasing recognition that economic policies, both sectoral and economywide, also significantly contribute to the problem. For example, the study links lowland poverty to agricultural taxation, price controls, and marketing restrictions, and uses an econometric model to demonstrate that the poverty contributes significantly to migration pressures on forest lands.

Trade and exchange rate policies have also played important roles in the Philippines and have been dominated by an urban consumer and industrial sector bias. The agricultural sector was implicitly taxed by an average of about 20 percent for most of the 1970s and early 1980s. Because the industrial sector did not provide an alternative source of growth, poverty generally has worsened and rural incomes in particular have suffered. The study results indicate that the main mechanism by which these economic problems affect the environment is through migration and the conversion of forest lands to unsustainable agriculture. Population pressure already evident in the 1970s worsened during the 1980s. The net upland migration rate grew from 3.4 to 9.4 percent between 1970 to 1975 and 1978 to 1980, and increased substantially to 14.5 percent between 1980 and 1985. Consequently, upland cropped area grew at annual rates exceeding 7 percent from 1971 to 1987. These results suggest that while forestry specific conservation programs are needed, economywide policy reforms could be as important in arresting the process of deforestation.

The environmental impact of reform policies depend largely on how the benefits are distributed among society. Several current studies point out that the benefits accruing to the poor, especially the rural poor, are disproportionately low. Based on a review of five structural adjustment programs (Côte d'Ivoire, Ghana, Indonesia, Philippines and Jamaica) a World Bank study showed that the poor benefitted mostly through indirect means such as the increase in demand for their services. Although incomes of farmers may increase due to higher prices for crops, the net effect of reform policies depends on whether they are net buyers of sellers. Price liberalization, elimination of subsidies on food products and high inflation often result in lowering the purchasing power of the poor in real terms.

A pattern of disproportionate distribution of benefits is illustrated in Zambia. The study contends that adjustment policies (elimination of government subsidies on food products, price liberalization measures, higher real interest rates and fiscal contractionary policies) will have a greater impact on the poor. Although a social action program targeting the services most crucial to the poor (i.e., health, nutrition and education) was developed, it received minimal funding.

In the case of Cameroon, the study explains that rural farmers were adversely affected by the reform policies. The overvalued exchange rate, combined with Cameroon's deteriorating terms of trade, created unfavorable conditions for the country's major export crops such as coffee and cocoa. The government was forced to reduce support prices by about 50 percent which amounted to a direct reduction of farmers' incomes. Between 1983 and 1993 the percentage of rural households living below poverty increased from 49 percent to 71 percent. Many farmers were forced to curtail investments on improving the land. Perennial cash crop cultivations were abandoned or converted into cultivation of subsistence based food crops – which generally implied more erosive and environmentally unsound practices. Farmers expanded cultivated areas; civil servants undertook farming on the side, to supplement their incomes. The overall result was increased pressure on forest lands and marginal lands.

The persistence of other economic distortions that have not been addressed in reform programs may also have a constraining effect on the environmental contribution of reforms. This is illustrated in studies of several Western African countries in the CFA franc zone. The CFA franc, which remained firmly linked to the French franc until January 1994, was highly overvalued throughout the duration of adjustment programs in countries, such as Cameroon. In spite of extensive stabilization and structural adjustment policies adopted by these countries the overall economic impact was limited. Thus, in Cameroon budgetary problems remained unresolved in spite of drastic measures to reduce public expenditure (Tchoungui et al 1994). The tradable goods sector suffered a major setback due to the overvaluation of the currency. As the formal sector declined, the informal sector expanded, particularly in urban areas. Along with a deterioration of social services such as health and education, these trends had a negative impact on poverty alleviation and on the environment.

Implications of the case study results

Effective decisionmaking for sustainable development has been hindered by lack of knowledge about the complex links between economywide policies and the environment. From the economic side, the environmental implications of macroeconomic policies and the adjustment process typically are inadequately explored, and from the environmental side, national environmental action plans rarely contain careful economic analysis. As described below, several practical steps to facilitate the integration of environmental and economic decisionmaking emerge from the case studies.

Integrating environmental concerns into economic decisionmaking

The preceding discussion shows that the links between economywide policy reforms and the environment can be complex and usually require country-specific analysis. However, although impacts are often too diverse to be *comprehensively* traced with precision, many key economywide reforms have specific, identifiable impacts on a much smaller subgroup of high-priority environmental problems. Some of these impacts may be intuitively obvious, and many of them, with some effort, may be traceable. Even modest progress in this regard is helpful because properly recognizing the environmental benefits of economywide policies will clearly help to build support for economic reforms. At the same time, broader recognition of the underlying economic and policy causes of environmental problems can enhance support for environmental initiatives—in terms of environmental policies as well as projects.

Positive or negative linkages may arise from relative price shifts—changes in the pattern of taxes, trade duties, real wages, exchange rates, and so on. For example, there are usually strong positive linkages between energy conservation and reforms in energy pricing, yet trade liberalization may encourage deforestation or overfishing in some cases. Where such negative linkages exist, the answer is not to delay stabilization or the adjustment program, but rather to devise specific measures, such as sensible forestry and fishing laws, to counteract the possible negative effects. In almost all cases, the foregoing conclusions are appropriate. However, it is conceivable that in rare cases involving severe environmental degradation (especially where ex ante analysis has carefully prepared the ground), special care may be required to orchestrate the timing and sequencing of various economywide policies and complementary environmental measures to minimize environmental damage.

The best approach to avoid environmental damage is thus to identify, prioritize, and analyze the most serious economic-environmental linkages and to devise specific complementary mitigating measures, when economywide reforms are contemplated. Where data and resource constraints preclude the accurate tracing of such links (ex ante), the preliminary screening and prioritization of environmental issues could be followed by the establishment of contingency plans and the careful monitoring of these environmental problems, to deal with them if they worsen ex post.

Action impact matrix: A tool for analysis

In the context of the foregoing discussion, economic and environmental analyses and policies may be used more effectively to achieve sustainable development goals by linking and articulating these activities explicitly. Implementation of such an approach is facilitated by constructing an action impact matrix (AIM)—a simple example is shown in table 2-1, although an actual AIM would be very much larger and more detailed (Munasinghe 1993a). Such a matrix helps to promote an integrated view, meshing economic decisions with high-priority environmental and social impacts. The first column of table 2-1 lists examples of the main development interventions (both policies and projects), while the first row indicates some of the main issues of sustainable development. Thus the elements or cells in the matrix help to (a) identify explicitly the key linkages, (b) focus attention on valuation and other methods of analyzing the most important impacts, and (c) suggest priorities for action. At the same time, the organization of the overall matrix facilitates the tracing of impacts, as well as the coherent articulation of the links between a range of development actions—that is, policies and projects.

A stepwise process, starting with readily available data, has been used effectively to develop the AIM in several country studies that have been initiated recently (for example, Ghana, Philippines, and Sri Lanka. First, data from national environmental action plans, environmental assessments, and so forth are organized into a table that prioritizes these problems, provides quantitative or qualitative indicators of damage, and identifies underlying economic causes. Second, the main economywide policies (current and intended) are set out in a second table, together with a brief review of the basic economic issues that they address and potential environmental linkages. The information from these two tables is then combined to develop a preliminary activity impact matrix. (For an example of the actual process used, refer to the appendix, in which table 2A-1 presents the environmental issues; table 2A-2 describes various economywide policy reforms; and table 2A-3 combines these two building blocks to produce an illustrative action impact matrix for Sri Lanka.)

One of the early objectives of the AIM-based process is to help in *problem identification* by identifying broad relationships, without necessarily specifying with any accuracy the magnitudes of the impacts or their relative priorities. For example, in table 2-1, a currency devaluation may make timber exports more profitable and lead to deforestation of open-access forest. The appropriate remedy might be to strengthen property rights or to restrict access to the forest areas. A second example might involve increasing energy prices toward marginal costs to improve energy efficiency and decrease pollution. Adding pollution taxes to marginal energy costs would further reduce pollution. Increasing public sector accountability would reinforce favorable responses to these price incentives, by reducing the ability of inefficient firms to pass on cost increases to consumers or to transfer their losses to the government. In the same vein, a major hydroelectric project is shown in table 2-1 as having two adverse impacts—inundation of forested areas and villages—as well as one positive impact—the replacement of thermal power generation (thereby reducing air pollution). A reafforestation project coupled with adequate resettlement efforts may help to address the negative impacts. The matrix-based approach therefore encourages the systematic articulation and coordination of policies and projects to achieve sustainable development goals. Based on readily available data, it is possible to develop such an initial matrix for many countries.

This process may be developed further to assist in *analysis* and *remediation*. For

Table 2-1. Action impact matrix (AIM)[1]

Activity and policy	*Main objective*	*Matrix of other impacts on key sustainable development issues*			
		Land degradation	*Air pollution*	*Resettlement*	*Others*
Macroeconomic and sectoral policies	Macroeconomic and sectoral improvements	Positive impacts are due to removal of distortions; negative impacts mainly due to remaining constraints			
Exchange rate	Improve trade balance and economic growth	(-H) (Deforest open-access areas)			
Energy pricing	Improve economic and energy use efficiency		(+M) (Improve energy efficiency)		
Others					
Complementary measures	Specific or local social and environmental improvements	Enhance positive impacts and mitigate negative impacts of broader macroeconomic and sectoral policies			
Market based	Reverse negative impacts of market failures and policy distortions		(+M) (Pollution tax)		
Nonmarket based		(+H) (Property rights)	(+M) (Public sector accountability)		
Investment projects	Improve efficiency of investments	Investment decisions are made more consistently with broader policy and institutional framework			
Project 1 (Hydro Dam)	Use project evaluation (cost-benefit analysis, environmental assessments, multicriteria analysis, and so forth)	(-H) (Inundation of forest)	(+M) (Displacement of fossil fuel use)	(-M) (Displacement of people)	
Project 2 (re-afforestation/ resettlement)		(+H) (Replanting of forests)		(+M) (Resettlement of people)	
. .					
Project N					

1. A few examples of typical policies and projects as well as key environmental and social issues are shown. Some illustrative but qualitative impact assessments are also indicated: thus + and - signify beneficial and harmful impacts, while H and M indicate high and moderate severity.
2. The AIM process focuses on the highest-priority environmental issues and related social concerns.
3. A list of market and nonmarket complementary environmental policies is given in the text.

example, more detailed analyses may be carried out for the subset of main economywide policies and environmental impact links identified in the cells of the preliminary matrix. This, in turn, would lead to a more refined final matrix, which would help to quantify impacts and formulate additional measures to enhance positive linkages and mitigate negative ones. The more detailed analyses that could help to determine the final matrix would depend on planning goals and available data and resources. They may range from the application of conventional methods of sectoral economic analysis (appropriately modified in scope to incorporate environmental impacts) to fairly comprehensive methods of system or multisector modeling. The former approach is used in many of the case studies mentioned above. The latter approach is illustrated by the Costa Rica and Morocco studies where computable general equilibrium models were constructed that include both conventional economic as well as environmental or resource variables. At the moment, data and analytical shortcomings are likely to preclude reliance on general equilibrium or comprehensive system modeling. Current efforts constitute a first step in this direction, their major contribution being to identify more precisely the information and data required for operational policy purposes and to test the strengths and limitations of a general equilibrium approach.

Thus far, the most successful attempts to value environmental impacts in the macroeconomic context have been based on their effects on conventional economic output that are priced in the marketplace (supplemented sometimes with shadow pricing corrections). This approach may be linked up more easily with commonly used market measures of well-being like gross national product. For example, the new United Nations handbook for the System of National Accounts includes a proposal to supplement the conventional system with a set of satellite accounts that reflect pollution damage and depreciation of natural resource stocks (United Nations Statistical Office 1993). Some environmentally and socially crucial impacts (for example, loss of biodiversity or human health hazards) may be as important in certain cases, and they may require extension or adaptation of conventional economic techniques. One step would be to improve environmental valuation by using a wider range of methods that employ both market and nonmarket information to estimate indirectly the economic value of environmental assets (for example, travel cost or contingent valuation methods). Such techniques have been used quite widely in project-level applications in the industrial countries (for a recent review, see, for example, Freeman 1993). There is a growing body of case studies on the environmental valuation of project impacts in the developing countries (for a recent review, see for example, Munasinghe 1993a, 1993b). However, considerable work is required to extend this experience to cover economywide impacts.

Other (noneconomic) indicators of environmental and social well-being (both micro and macro) also would be helpful in decisionmaking, especially in cases where economic valuation is difficult. Techniques such as multicriteria analysis may be used to trade off among economic, social, and environmental indicators, as a supplement to conventional cost-benefit analysis. The Sri Lanka case study explores the multicriteria analysis approach, in attempting to analyze economic-environmental as well as environmental-environmental tradeoffs. The essential point is that even when environmental valuation is not possible, techniques exist that will help to prioritize environmental and social impacts better, thereby improving development actions.

Identifying economic-environmental links

As shown above, improving the integration of environmental issues in economywide policy analysis will help to generate support for economic reforms. However, this can also improve the policy context for environmental initiatives. Implementation of projects that have environmental objectives or components has always been a problem. This difficulty stems from the fact that it may not be in the narrow self-interest of the borrowing entity to adhere to loan conditions that are primarily of benefit to others in the country. At the national level, enforcement of standards and regulations often encounters severe institutional constraints. Part of the solution is to create conditions in which the interests of the party causing environmental damage coincide with the social good—integration of environmental concerns into sectoral and macroeconomic incentives is therefore required.

Overall, the studies discussed earlier suggest that economic techniques exist—and for most countries, so does natural resource information—to improve the way environmental issues are addressed by policies at the sector and macro levels. Although data problems remain, the studies illustrate the feasibility of carrying out better analyses of the environmental impact not only of projects, but also of economic policies—and in particular—adjustment operations. This would hasten the integration of the environment into the mainstream of economic policymaking. Where the environmental impact of the adjustment process is potentially adverse, such studies would form the basis for identifying measures to counteract these effects (both ex ante and ex post); where, in contrast, they are likely to be positive, complementary measures might be devised to maximize such beneficial impacts. This approach is consistent with and supports project environmental assessment procedures that already exist in most countries. Although the function of environmental assessment as a proactive instrument of project preparation and design is clearly understood in theory, more could be done to achieve this objective in practice. The add-on nature of environmental concerns, the lack of breadth in identifying relevant issues, the limited attention to alternatives, and the weakness of mitigation plans in some projects show this to be the case. Clearly, the search for fundamental underlying causes of environmental degradation and the design of economic and other instruments at the country or sector level could substantially support the environmental assessment process at the project or investment level.

The lessons from the case studies are also relevant from the viewpoint of the persons and agencies with explicit environmental responsibilities, including preparation of national environmental action plans. These documents have rarely responded adequately to the growing need to understand the links between economic policies and the environment, and to date apparently no case study has conducted a systematic analysis of the economic policies underlying environmental degradation and, therefore, of the appropriate ways in which environment should become part of countrywide economic planning. In providing examples to the persons responsible for environmental management of the way in which economic policies may affect the environment, this chapter also demonstrates the kinds of opportunities available for achieving environmental objectives, not simply in a cost-effective manner, but indeed often in ways that impose no costs at all on society. Such opportunities should receive systematic attention in national environmental action plans, which would then become much more operationally useful inputs into decisionmaking at the macroeconomic or sector policy level.

Summary and main conclusions

Specific Findings

In summary, the specific findings emerging from the case studies can be grouped according to the principal ways in which economywide policies interact with the environment, highlighting how they might help in the design of better adjustment programs.

- *Removal of major price distortions, promotion of market incentives, and relaxation of other constraints (which are among the main features of adjustment-related reforms), generally contribute to both economic and environmental gains.* Reforms that improve the efficiency of industrial or energy-related activities can reduce both economic waste and environmental pollution. Similarly, improving land tenure rights and access to financial and social services not only yields economic gains but also promotes better environmental stewardship.
- *Unintended adverse side effects may occur, however, when economywide reforms are undertaken while other neglected policy, market, or institutional imperfections persist.* Therefore, specific additional measures that remove such policy, market, and institutional difficulties are not only generally environmentally beneficial in their own right but also critical complements to broad economywide reforms. Typical examples include:

  Policy distortions. Export promotion and trade liberalization might encourage excessive extraction or harvesting of natural resources if the latter were underpriced or subsidized, for example, low stumpage fees for timber.

  Market failures. Economic expansion induced by successful adjustment may be associated with excessive environmental damage, for example, if external environmental effects of economic activities (such as pollution) are not adequately reflected in market prices.

  Institutional constraints. The environmental and economic benefits of economywide reforms could be negated by the failure to address institutional issues, for example, poor accountability of state-owned enterprises, inadequate land titling, or weak financial intermediation.
- *Measures aimed at restoring macroeconomic stability generally yield environmental benefits, because instability undermines sustainable resource use.* For example, stability encourages decisionmakers at all levels to take a longer-term view, while lower inflation rates lead economic agents to send clearer pricing signals and make better investment decisions. These are essential prerequisites for encouraging environmentally sustainable activities.
- *The stabilization process also may have unforeseen adverse short-term impacts on the environment.* For example, although general reductions in government spending are deemed appropriate, targeting these cutbacks is desirable to avoid disproportionate penalties on environmental protection measures. Another important issue is the short-term impact of adjustment on poverty and unemployment, which may aggravate existing pressures exerted on fragile and open-access resources by the poor due to the lack of economic opportunities. In this case, appropriate measures designed to address the possible adverse social consequences of adjustment are justified even further on environmental grounds.
- *Economywide policies have additional longer-term effects on the environment through changes in employment and income distribution.* Several of the examples confirm one predictable conclusion: adjustment-induced changes generate new economic opportunities and sources of livelihood, thereby alleviating poverty and reducing pressures on the environment due to overexploitation of fragile resources by the unemployed. However, although growth is an essential element of sustainable development, it necessarily increases pressures on environmental resources. Increasing efficiency and reducing waste, as well as properly valuing resources, help to reshape the structure of growth and reduce undesirable environmental impacts.

Practical implications

Although the relationships between economywide policies and the environment are complex and involve many economic and noneconomic variables, decisionmakers can initiate immediate steps to improve understanding and to start to address some of these linkages. Proper recognition of the generally positive environmental consequences of economywide policy reforms could help to build additional support for such programs. At the same time, broader recognition of the underlying economic and policy causes of environmental problems can enhance support for environmental initiatives. The following are key practical steps that can be taken:

- *Problem identification.* More systematic efforts are needed to monitor environmental trends and anticipate emerging problems when policy reform proposals are being prepared. The range of currently available environmental information should be analyzed to help to identify the highest-priority preexisting or emerging environmental problems and their sensitivity to policy measures. Recently initiated work on environmental indicators in the World Bank will help to supplement existing data.
- *Analysis.* Serious potential environmental impacts of proposed economywide reforms identified in the problem identification stage should be subjected to careful environmental analysis—to the extent that data and resources permit. Many of the techniques and examples presented in this chapter will be helpful in tracing the simpler and more obvious links between economywide policies and the environment.
- *Remedies.* Where potential adverse impacts of economywide reforms can be identified, targeted complementary environmental policies or investments should be implemented as soon as feasible to mitigate predicted environmental damage and enhance beneficial effects. Where linkages are difficult to trace ex ante, greater reliance needs to be placed on preparing contingency plans to be invoked ex post.
- *Follow-up.* A follow-up system for monitoring the impacts of economic reform programs on environmentally sensitive areas should be designed and resources made available to address environmental problems that may arise during implementation.

The complementarity of economic and environmental measures for sustainable development should be used to mobilize more environmental support for economic reforms, and vice versa. However, the difficulties of analyzing the potential environmental impacts of proposed economywide reforms (ex ante) should not be underestimated. Linking specific causes with particular effects is especially problematic in countries where many conditions are simultaneously changing. Nevertheless, many direct linkages may be traced using existing methods. Because improving the incorporation of environmental aspects into economic policymaking could result in substantial gains (particularly in the context of adjustment operations), more analytical work is needed to understand the complex links involved. Due to the significance of social and institutional constraints to sustainable development, more attention should be paid to analysis of the social impacts of economywide reforms.

This chapter indicates how the analytical process may be strengthened, starting from fairly simple considerations. The various relationships identified here, although based on country-specific work, have been used to develop a general framework based on the concept of the action impact matrix, which more clearly identifies a country's environmental problems in relation to its program of economywide policy reforms and major projects. This stepwise approach focuses initially on the links between a relatively small subset of priority environmental concerns and a few key economic policy reforms. In subsequent stages, the analysis may be made much more comprehensive.

Notes

Related findings of relevance to World Bank environmental activities are discussed in Munasinghe and Cruz (1994). The authors are grateful to Noreen Beg, Shreekant Gupta, and Adelaida Schwab for their help in various sections of the paper. They also acknowledge the many comments and suggestions received from colleagues within the World Bank and from the community of development and nongovernmental organizations. The authors are, of course, solely responsible for the contents of this work.

1. The researchers involved in each case study are cited in the text.
2. The effect of inadequate tenurial security over the resource (and future benefits from it) parallels the results for high discount rates. This corresponds with the well-known result in renewable resource exploitation models: that the effects on economic behavior of open-access resource conditions are formally equivalent to those of having secure property rights with infinitely high discount rates.

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Appendix 2-1. Developing an action-impact matrix: an example from Sri Lanka

Table 1. Indicators and Causes of Selected Environmental Problems in Sri Lanka

Environmental Areas of Concern	Bio-physical Indicators	Socio-economic Indicators	Underlying Causes: Economic Policies, Prices and Institutions
Soil Erosion and Degradation	Increasing pressure on land (land-human ratio has declined to 0.38 ha), as economic growth continues to impinge on agricultural land. Cultivation of marginal lands, particularly the shallow and lateritic soils of the wet zone, results in erosion and landslides. Forests have been removed from steep slopes for tobacco cultivation. Erosion rates in neglected tea lands (up to 30% of total area under tea) are as high as 40 tons/ha/yr, compared to an achievable rate of 0.3 tons/ha/yr. In the dry zone where land is flat, erosion is not a severe problem. However, chena (shifting) cultivation is now practiced with greater intensity and very short fallow periods have replaced the traditional longer periods that made the system sustainable. As a result, soil is becoming infertile and about 1.2 million hectares of land (mostly in the dry zone) are now degraded. Severe land degradation due to gem mining in specific areas (mostly in Ratnapura district).	Productivity losses due to soil erosion estimated in the range of Rs. 613 to 4,283 million annually. Tea yields only 52-64% of yields in Indonesia, India, Malawi, and Kenya. Severe erosion has led to the Polgolla reservoir silting up to 45% of its capacity after only 12 years of operation, resulting in reduced irrigation water and electricity generation, as well as greater flooding.	Land markets are very limited and the resource is severely underpriced. This leads to inefficient and distorted land allocation decisions. Land tenure system results in disincentives for long-term soil conservation measures. This includes poorly managed state-owned tea and rubber plantations. Higher protection for erosive crops (e.g., potatoes). In the case of gem mining, lack of environmental or rehabilitation charges encourages small-scale pit mining operations which do not reflect the social cost of these activities.
Deforestation and Biodiversity Loss	Decline in forest cover from 55% of total area (1950s) to 28% (1980s). NEAP estimates forest area in 1989 at 1.58 million ha (24% of total area), with closed canopy forest down to 20%. Deforestation rate is estimated to be 30,000-50,000 ha/yr.	Decline in sustainable timber yield due to deforestation is estimated at Rs.300 million annually. The wood industry also has been forced to shift to lower quality wood. In addition, conversion of forest land to chena, poorly managed plantations, or food crops result in soil erosion and significant loss of productivity.	Low timber charges (royalty only 10% of sales value) encourage over-extraction of this resource. Demographic pressures and landlessness lead to encroachment onto forest lands (80% of which are state-owned, but are *de facto* open access).

Table 1 (continued). Indicators and Causes of Selected Environmental Problems in Sri Lanka

Environmental Areas of Concern	Bio-physical Indicators	Socio-economic Indicators	Underlying Causes: Economic Policies, Prices and Institutions
Urban and Industrial Pollution	Less than 20% of the population of Colombo Metropolitan Area (CMA) is served by sewers. Less than half of CMA's daily solid waste disposal of 1,200 tons reaches landfills. Similar situation prevails in other urban areas as well. CMA is the only urban area with a (partial) sewer system.	Diseases associated with pollution and poor sanitation constitute the number one cause of morbidity and mortality in CMA. Nation-wide, the rate of intestinal infections more than doubled to 1,025 per 100,000 population between 1965-84.	Absence of user fees for municipal services results in poor quality of services and financially weak municipalities that are dependent on government grants. Lack of effluent/emission charges implies that activities that generate them do not internalize the costs of these damages.
Water Pollution and Water Shortage	Water shortage in areas other than the western part of the wet zone. Sedimentation of reservoirs and canals in irrigated areas in the dry zone. Salinity and waterlogging in downstream lands also a growing problem. Fertilizer residues from paddy cultivation contaminate surface and sub-surface water. Poor fertilizer storage is one of the main causes of groundwater pollution. Extensive water pollution in urban and industrial areas. Nearly 75% of Colombo's untreated sewage is discharged into the lower Kelani river. Water quality at the city's water intake at Ambatale often unfit for public water supply.	A disproportionate share of public investment has been allocated to irrigation, particularly the Mahaweli project (public expenditure on this project alone accounted for 7% of GDP in 1982). However, the returns have not been commensurate. Water use is inefficient (biased toward paddy cultivation). Large volume of water is unaccounted for (39% in Colombo) due to leaks, faulty meters and illegal connections. The irrigation infrastructure is deteriorating prematurely: funds allocated for operation and maintenance cover only 40 to 60% of the actual requirement. Small size of holdings (1 ha) in Mahaweli, and the incentives provided by subsidies, trade policy and research and extension contribute to excessive concentration on (water intensive) paddy cultivation, as do land-use and cropping restrictions. Area under high value added cash crops is limited in the Mahaweli, implying sub-optimal use of irrigation water. National water tariff is below marginal cost and the collection system is relatively ineffective. Cross-subsidies (from low cost to high cost regions and from Greater Colombo to the rest of the country), discourage conservation.	Lack of effluent charges or enforceable standards. Fertilizer subsidies result in misallocation of resource inputs to agriculture.

Table 1 (continued). Indicators and Causes of Selected Environmental Problems in Sri Lanka

Environmental Areas of Concern	Bio-physical Indicators	Socio-economic Indicators	Underlying Causes: Economic Policies, Prices and Institutions
Marine and Coastal Resource Degradation	One-third of the coastline (1,600 km) is subject to varying degrees of erosion. Average annual rates on the southwestern and western coasts range from 1 to 7 meters. Extensive sand and coral mining aggravate erosion. The latter is most severe along southwestern coast, where approximately 7,700 tons of coral and coral debris are collected annually along a 60 km stretch. Sedimentation and run-off from rivers and agricultural lands, and inappropriate infrastructure also lead to coastal and marine degradation. There is a growing list of mangrove areas and lagoons that have been seriously damaged by pollution.	Potential sites for managed sand mining have largely disappeared. Coastal fisheries have declined. Coastal tourism potential in sites such as Hikkaduwa and Bentota is threatened by fecal pollution of beaches and coastal waters. (About 85% of tourist revenue comes from facilities in coastal areas.) About 75% of graded hotels and over 80% of hotel rooms are located along the coast. Thus, tourism is threatened by (as well as a cause of) marine and coastal resource degradation.	Virtual open access to coral reefs and coastal fishery resources. Excessive reliance on legislation and laws for the protection of coastal resources. Mining of sea coral in the coastal zone (a punishable offence under the Coast Conservation Act), continues unabated. Though the demand for coral is a *derived demand* for construction, there has been no focus on economic incentives for reducing this (derived) demand by encouraging alternative construction materials. In terms of agro-chemical runoff, fertilizer and pesticide subsidies are a major cause of overuse.
Energy Shortage	Fuelwood accounts for 70% of energy consumption, and is used for cooking by 94% of households. Fuelwood shortage in the dry zone by 1995 and for the entire country by 2000. No domestic petroleum. All large hydro-power resources (50% of hydro potential) already exploited.	Both industry and households generally do not practice energy conservation. Thermal efficiency of traditional stoves is 10-15%.	Electricity tariffs are low. Even after a 30.5% increase in 1993, average tariff (6 cents/kWh) is approximately two-thirds of the long run marginal cost (LRMC). Household consumers are cross-subsidized (some pay only 15% of LRMC). Uneconomic rural electrification schemes are a burden on the Ceylon Electricity Board.

Table 2. Current Economic Conditions and Proposed Reforms in Sri Lanka

Economic Policies	Current Situation/Policy Issues	Ongoing/Proposed Reforms and Implications	Environmental Implications
Government Budget	Deficit has crowded out the private sector and driven up real interest rates. It was 11.6% of GDP in 1991. However, in 1992, a 1% reduction in current expenditure and a sharp drop in capital expenditure reduced the deficit to 7.5%, well below the target of 8.6%. It went up to 8.1% of GDP in 1993, and may worsen in 1994.	Reduce overall deficit (excluding official grants) to 6.5% of GDP in 1994, through improved revenue performance, consolidation of current expenditures, and rationalization of the public investment program. Reduce deficit to $\leq$ 6% in long-run.	A lower inflation rate, reduction in government deficit, downsizing of the public sector, and rationalization of the tax structure, all contribute to stable expectations and create an environment conducive to private capital formation (as well as replacement of capital stock).
(i) Government Expenditures	Some misallocation, including large, unviable investment programs; inadequate maintenance expenditures; and excess spending on defense and debt servicing.	Limit large village-level public works programs; administrative reform, including civil service reform; US$ 600 million Airbus purchase by Air Lanka should be reconsidered and scaled down.	Newer capital is generally cleaner and technologically more efficient. In a stable macroeconomic climate, long-term investment planning is more feasible.
(ii) Public Enterprises	Losing money: losses at 8 largest public enterprises accounted for half of the deficit in 1991; 2 insolvent state-owned banks with 2/3 of total assets in the banking sector, required a massive capital injection from government in 1993.	Half of small/medium enterprises already privatized or divested. Complete the privatization of small/medium enterprises, start with large ones (Air Lanka, sugar factories, cement companies, tea plantations). Also see *Industry* following. However, there is no sign that hard budgets will be imposed on the ones that remain state-owned, e.g., Ceylon Electricity Board (CEB), Sri Lanka Railways (SLR) and Ceylon Petroleum Corporation (CPC). CEB's tariffs are to be increased in 1994 & 1995. SLR has been made into an autonomous corporation and an IDA-assisted restructuring program is under way.	However, an expansion in economic activity could lead to more pollution overall (*scale effect*) even if there were less pollution per unit of output (*intensity effect*). Quick reductions in government expenditure may be achieved through disproportionate cuts in environmental expenditures and social sector spending, but this may in fact be harmful for long-run economic growth. This underscores the fact that the *quality* of fiscal adjustment is as
iii) Tax Policy	Substantial reliance on indirect taxation (83%); arbitrariness (proliferation of tax holidays, ad hoc tax concessions).	A VAT was planned for 1994, but has been postponed by a year to April 1995. Progress in computerizing returns continues to be slow. Corporate income tax reduced to 40%; elimination of export taxes; simplification of turnover tax (rate bands reduced from 10 to 3).	important as *quantitative targets*.

Table 2 (continued). Current Economic Conditions and Proposed Reforms in Sri Lanka

Economic Policies	Current Situation/Policy Issues	Ongoing/Proposed Reforms and Implications	Environmental Implications
Infrastructure/ Energy	Transport, telecommunications, electricity generation are heavily concentrated in the public sector; backlog of necessary rehabilitation and maintenance works; inadequate cost recovery; regulatory framework inhibits private sector entry. Ceylon Electricity Board (CEB) and Sri Lanka Railways (SLR) face financial problems; they require tariff and fare hikes. In the CEB, tariffs are well below long-run marginal cost (LRMC). Level and structure of petroleum prices out of line with border price relatives; public import monopoly of petroleum products. The massive Mahaweli project has been going on since 1970 (almost complete now) to provide irrigation and electricity. It is the government's largest investment project: over 43 billion rupees had been spent by 1987 and the total expenditure was then anticipated at 60 billion rupees. (Sri Lanka's GDP in 1987 was 200 billion rupees.)	Sri Lanka Telecom Department is now a public corporation. In addition, there is now a limited role for private services in this sector. Sri Lanka Railways has been converted from a government department to an independent authority. No increase in long-awaited tariff and fare revisions for CEB and SLR, respectively; no indication that tariffs in the infrastructure sector in general will be increased toward LMRC. BOO/BOOT (Build-Operate-Own/Build-Operate-Own-Transfer) schemes are being actively pursued in the power sector. Private sector entry allowed in petroleum sector (e.g. blending plant and blending services privatized and divestiture of retail stations is ongoing). Inadequate operation and maintenance (O&M) is already causing premature deterioration of the infrastructure. It is now necessary to focus on maintenance and rehabilitation rather than further investment. Studies by International Irrigation Management Institute (IIMI) indicate there is no economic justification to increase irrigated area such as through the Kalu Ganga project.	Progressive privatization of the infrastructure and energy sectors and accompanying price reforms (LRMC pricing) should increase their efficiency and also encourage optimal use of water, energy, etc. This would not only reduce the resource costs of economic growth, but also be beneficial for the environment. Rehabilitation of the irrigation network could reduce water loss and associated environmental problems such as waterlogging and salinity.

Table 2 (continued). Current Economic Conditions and Proposed Reforms in Sri Lanka

Economic Policies	Current Situation/Policy Issues	Ongoing/Proposed Reforms and Implications	Environmental Implications
Industry/ Mining	Manufacturing, the most dynamic sector in the economy, grew at 9% in 1992. Private sector grew at 20% and its performance overshadows the sluggish public sector. Foreign investment remains strong. This should enable the economy to grow and diversify its industrial and export base. Garment industry highly successful (partly due to import quotas in the European Union and USA). The government set up 200 rural clothing factories by the end of 1992 to promote job growth in rural areas and reduce the current concentration around Colombo--however, many may not be economically viable; also, this is the only major non-agricultural manufactured export. A recent agreement with the USA, which accounts for 65% of all garment exports, increased quotas by 16%, and the start of the quota year was brought forward to January from July.	Privatization continues, and 23 state enterprises had been privatized by the end of 1992. However, plans to privatize Air Lanka and the two state-owned banks have not taken off. Following protests from local gem miners and environmentalists, in January the government banned mechanized gem mining in all rivers and stream beds in Sri Lanka. (Possible environmental impacts: destruction of river fauna, lowering of surrounding water table, collapse of river banks leading to flooding in heavy rains.) Comprehensive new mining regulations introduced under an Act in 1992. All current licensed and unlicensed operations involved in exploration, mining, processing, trading or export of minerals must acquire *new licenses* under the act. The act does not cover gems and hydrocarbons.	Privatization and economic reforms lead to greater efficiency in resource use. Pollution intensity declines as resources are used more efficiently (*intensity effect*). However, overall pollution may increase due to increase in total output (*scale effect*). Unless costs of pollution are internalized, profit-maximizing private firms may now substitute "free goods" (such as the environment) for purchased inputs in the production process. (In other words, to the extent that such substitution possibilities exist, private profit-maximizing firms are more likely to exploit them than state-owned enterprises (SOEs)). Closure of the more inefficient SOEs may reduce overall pollution. Elimination of subsidies for inputs such as electricity or water leads to more efficient use and as a consequence, less pollution. Greater inflow of modern technology through foreign collaboration could reduce pollution intensity.

Table 2 (continued). Current Economic Conditions and Proposed Reforms in Sri Lanka

Economic Policies	Current Situation/Policy Issues	Ongoing/Proposed Reforms and Implications	Environmental Implications
Agriculture	Sluggish growth and narrow export base due to (i) excessive government intervention in pricing and trade; (ii) public expenditure excessively oriented toward self-sufficiency in food (free land and water inputs); (iii) poor O&M of existing irrigation infrastructure. Dominant crops are paddy, tea, rubber and coconut. Most rubber and tea are exported. Tea: Output almost back to normal in 1993 after the drought-affected slump of 1992 (also due to privatization of plantation management). World demand is high and prices are firm. There is an urgent need to modernize tea industry and increase output of CTC tea (for Western markets) compared to orthodox teas. (In 1993 CTC tea accounted for only 3.4% of total output, rest was orthodox tea--this could be a big problem in the future.) Tea growers also hampered by high interest rates. Another major problem is advanced age of tea bushes--in 1987 average age was approximately 60 years. Only 15% of the area under tea has been replanted with HYVs. Low replanting in 1960s and 1970s because high export taxes plus low tea prices meant low profits; also there was a risk of nationalization.	Insufficient political will to implement meaningful reform, especially to relax legislated cropping and land-use restrictions and to remove non-tariff barriers. Export crop taxation, however, being phased out; rationalization of sugar industry (including privatization of factories); rice, wheat and flour markets partially deregulated; tea and rubber plantations contracted out to private management companies (see below); Mahaweli restructuring plan under preparation. The government is offering cash subsidies per hectare to tea smallholders as well as rebates on fertilizers (trade-off needed since fertilizer subsidies are bad for the environment, but required to increase production); tea marketing system to be reformed; regulations on tea growing relaxed--growers do not have to register tea holdings with the Tea Commissioner or obtain permits for planting and replanting, establishing nurseries or factories, or selling tea locally. There is a proposal to conduct the Colombo tea auction in dollars rather than rupees (enabling planters to borrow working capital in foreign currency, at much lower interest rates).	Reforms in management of the tea sector should encourage better stewardship of natural resources such as soil and water. Current 30 year leases are a distinct improvement over the earlier 5 years, which encourage deforestation of plantation forests for quick profits. This underscores the importance of *ownership* issues for the environment. Eventual privatization of these plantations (presumably once they are profitable) would further encourage long-term investments to increase productivity, e.g., soil conservation and replanting (which are also good for the environment). Given other distortions such as underpricing of timber, rapid privatization could lead to deforestation of forests on plantation lands (for short-term profits). Deforestation of plantation forests could also occur in response to rapid growth in tea output--for use as firewood in tea factories.

Table 2 (continued). Current Economic Conditions and Proposed Reforms in Sri Lanka

Economic Policies	Current Situation/Policy Issues	Ongoing/Proposed Reforms and Implications	Environmental Implications
Agriculture, continued	**Rubber:** A large number of plantations suffer from old age and neglect; output and area have been declining since the 1980s. **Coconut:** Like tea and rubber, suffers from inadequate replanting. Large proportion of trees are old and past optimum productivity levels. Output is on a declining trend due to recurring droughts and withdrawal of fertilizer subsidies.	Smallholders who produce the bulk of the coconut output have not taken advantage of several subsidy schemes that the government has offered to encourage coconut production.	Subsidies on fertilizer in the past may be encourage overuse and resulted in acidification of soils, nutrient imbalances, and soil erosion. This is in addition to downstream pollution of surface and groundwater from agro-chemical runoff.
Forests	Continuing deforestation and degradation of forests through illicit felling and encroachments which are periodically "regularized"; lax implementation of statutes for limited felling; many good plans on the books but not implemented. The Forestry Master Plan (1987) is the blueprint for this sector for the next two decades. While a large reforestation program has been implemented, essential follow up silvicultural operations are frequently neglected.	The Master Plan envisages clearing all 1.3 million ha. of dry zone forest (except 0.5 million ha. set aside for national parks). The remaining forests are in the wet, intermediate and montane zones (278,000 ha.). Of these, 159,000 ha. (57%) will be protected and the rest selectively cut. The Plan also recommends reintroduction of the cooperative reforestation scheme (a highly successful program for raising industrial wood plantations in the dry zone). A five year program to improve forestry conditions and management started in 1990.	Economic growth and job creation, particularly in the manufacturing sector, may reduce pressure on agriculture, especially on chena cultivation which is the main cause of deforestation. As the construction sector grows, however, domestic demand for wood will increase. Completion of the Mahaweli project should provide extra land and energy that may also reduce the derived demand for deforestation (for agriculture and fuelwood). Removal of price distortions in timber (royalty only 10% of sale price) would also reduce incentives for deforestation.

Table 3. Sri Lanka Action Impact Matrix (Selected Elements)

Economywide Policy Reform Goals/ Instruments	**Sustainable Development Issues**					
	Urban and Industrial Pollution	**Forest and Biodiversity Protection**	**Agricultural Land Conversion and Degradation**	**Energy Generation and Conservation**	**Water Resources Depletion and Degradation**	**Coastal Resource Degradation**
Sectoral/Inter-sectoral Price and Institutional Reforms (i) Resource Access Rights and Tenure	[+] property rights allowing community -based manageme nt of coastal areas and coral reefs could strengthen incentives to reduce industrial and agricultural pollution	[+] decen-tralization and social forestry-type institutional support will reduce open-access exploitation of forest and wildlife resources	[+] tenurial security will promote invest-ment and improve land management (note: in some cases, privatization may be externally imposed on communally managed lands, leading to a breakdown of traditional management systems)			[+] intro-duction of community rights over fishing & mangrove resources would encourage better resource management
(ii) Price and Subsidy Reforms			[+] removal of subsidies will encourage more efficient/reduced use of agricultural chemicals	[+] improving energy prices will promote more efficient energy generation and use [-] higher prices may reduce access to the poor	[+] introducing higher industrial and irrigation water fees will encourage efficiency in water supply and use [-] higher prices may reduce access to the poor	

Table 3 (continued). Sri Lanka Action Impact Matrix (Selected Elements)

Economywide Policy Reform Goals/ Instruments	Sustainable Development Issues					
	Urban and Industrial Pollution	Forest and Biodiversity Protection	Agricultural Land Conversion and Degradation	Energy Generation and Conservation	Water Resources Depletion and Degradation	Coastal Resource Degradation
Privatization (i) Improve Efficiency in Use of Resources (e.g., with financial reforms and hard budget constraints)	[+] reduce waste in resource-based manufacturing		[+] increase efficiency of tea plantations, leading to better land management (note: in communally managed lands, privatization may be associated with negative effects, as discussed under institutional reforms above)	[+] increase efficiency of generating plants; with pricing reforms (see below), it will also increase energy efficiency among industrial users	[+] promote more efficient provision of urban and industrial water supply	
(ii) Promote Private Investment	[+] private investments tend to introduce less polluting technology	[+] alienating land for plantations or allowing sufficiently long-term leases could promote plantation development	[+] may increase investment in land improvement	[+] new plants tend to be more energy efficient	[-] together with price increases, this may reduce access to water by the poor	

Table 3 (continued). Sri Lanka Action Impact Matrix (Selected Elements)

Economywide Policy Reform Goals/ Instruments	Sustainable Development Issues					
	Urban and Industrial Pollution	**Forest and Biodiversity Protection**	**Agricultural Land Conversion and Degradation**	**Energy Generation and Conservation**	**Water Resources Depletion and Degradation**	**Coastal Resource Degradation**
Government Deficit Reduction (i) Cut Expenditures, Reduce Subsidies	[-] social and environmental programs like urban pollution abatement (e.g. MEIP) are often the first to be cut; poor communities often at risk	[-] protection efforts may be reduced especially in forestry (e.g., Forest Department budget constraints)	[-] reduced agricultural extension programs, increasing problem of chena cultivation, soil erosion	[+/-] reduced energy subsidies also control wasteful energy use, but may reduce access to the poor	[+/-] reduced subsidies will discourage wasteful water use, but poor communities may have reduced access to safe supplies	[-] coastal/coral reef protection efforts may further decline (e.g., CEA, NARA budget constraints)
(ii) Introduce Resource Rent Taxation and User Charges		[+] reduce pressures on use of forests and protected areas and raise funds to improve community self-management or government protection services	[+] taxation of idle or neglected lands will encourage land improvement		[+] encourage more efficient use of water sources	[+] promote more efficient use of coastal resources
(iii) Introduce Environmental taxes and fees (in contrast to above instruments, these are charges on environmental externalities)	[+] taxes or charges on emissions or effluents will increase incentives for abatement; may also reduce land degradation from mining	[+] reforestation deposits could encourage sustainable logging		[+] introduce incentives to reduce emissions or effluents in energy generation	[+] tailings or discharge fee will reduce water degradation problems	[+] charges or penalties would discourage coral reef and mangrove degradation

Table 3 (continued). Sri Lanka Action Impact Matrix (Selected Elements)

Economywide Policy Reform Goals/ Instruments	Sustainable Development Issues					
	Urban and Industrial Pollution	Forest and Biodiversity Protection	Agricultural Land Conversion and Degradation	Energy Generation and Conservation	Water Resources Depletion and Degradation	Coastal Resource Degradation
Trade Promotion (i) Export Promotion and Foreign Exchange Liberal-ization		[-] export stimulus may increase timber cutting -- depending on land tenure and account-ability, this may worsen deforestation	[+/-] both crop output and input prices will be affected if they are tradables; better land management is encouraged by higher crop prices if tenure is secure (see tenure issue above)	[-] outward-oriented growth will increase energy generation needs		
(ii) Reduce Tariffs and Other Trade Barriers	[+/-] industrial openness is associated with new and more efficient technologies, but absolute pollution levels may increase with rapid sectoral growth		[+/-] may initially affect industrial output and employment as inefficient firms fail to compete with imports; long-run improvements in resource allocation should increase employment and income, reducing pressures for marginal resource exploitation			
Industrial Promotion (i) Reduce Special Industry Programs and Investment Subsidies	[+] special government industrial projects tend to favor industries (especially parastatals) that are often pollution prone; thus, reducing direct government programs will help improve the structure of industrial production		[+] increased industrial employment may reduce pressures on marginal lands			[+] promo-tion of tourism will create new jobs in coastal areas, thus relieving pressure on coral mining and over exploitation of fisheries

3

Environmental Impacts Of Structural Adjustment Programs: Synthesis and Recommendations

Theodore Panayotou and Kurt Hupé

The concern with the environmental impacts of structural adjustment programs and other economywide policies is the product of the growing realization of the interdependence between economy and environment which began to gather momentum in the late 1980s and culminated with the 1992 UN Conference in Rio on Environment and Development. Following the Rio Conference, the debate moved one step further, from assessment of the passive impact of development policies on the environment (and of possible mitigation measures), to their dynamic interaction and the need for holistic integration of economy and environment, or what has come to be known as sustainable development.

Since structural adjustment policies predated the concept of sustainable development as the objective of development assistance and policy, it is of considerable interest to explore the extent to which economywide policies have revolved or, at least, evolved to realign themselves with the concept of sustainable development through ex ante integration with social and environmental policies. This is the objective of the present chapter. The inquiry will be carried out on two levels: first, by surveying the findings of studies that attempted ex post assessment of the environmental impacts of structural adjustment programs and the way in which they have been addressed; second, by examining the progress of successive structural adjustment programs in incorporating environmental concerns; and ultimately, in attempting holistic integration of economic, social, and environmental policies.

The field of inquiry that falls under the rubric of structural adjustment and the environment is a young and complex one. First, it involves the intersection of both social and natural sciences (economics, public policy, international development, biology, ecology, and so on), and existing studies often lean heavily on a single perspective at the expense of holistic, interdependent interpretations. Second, less than a decade has passed since a quorum of researchers began focusing their analyses specifically on the environmental effects of structural adjustment in developing countries; thus the coverage of existing studies specific to this area is incomplete, both geographically and in terms of natural resource factors examined. Third, the boundaries between this subject area and other, perhaps more well researched, areas are fuzzy or broadly overlapping. Examples include debt and environment, trade and environment, poverty and environment, and sustainable development in general. The potential depth and breadth of information relevant to structural adjustment and the environment is immense. The following discourse attempts to narrow the focus to the environmental implications of the economic reforms in structural adjustment and stabilization programs. Related materials are drawn into the analysis where there appear to be significant gaps in the directly relevant literature.

The major question explored in this chapter is: "What are the environmental effects of stabilization and structural adjustment programs?" Implicit in this question is a desire for policy makers and advisors to provide the appropriate recommendations to ensure a healthy environment and economy for the nation undertaking structural reform. Unfortunately, the only concise answer to the question would be that it depends on a number of factors, implying that economic policy makers cannot apply a simple, standardized set of reforms to any given economy and expect predictable, consistent, or even beneficial results.

Consider an analogous question, outside the economic and policy realm: "What are the overall health effects of a diet and exercise program?" Assuming a subject in average shape, a few pounds overweight, with an adequate but imperfect diet, and with a commitment to the program, an attentive counselor can provide the correct nutritional and exercise advice to enhance the subject's health and well being. But if the subject's condition differs from the assumptions, perhaps because of chronic back problems, chemical abuse, obesity, malnourishment, special dietary needs, or, most importantly, a lack of commitment to wellness, the same nutritional and exercise regimen could fail, yield mixed and unpredictable results, or even kill the subject.

The findings of this study are comparable. Given an economy with more or less efficient (or at least existent and reasonably functioning) markets, infrastructure, and institutions; some fiscal difficulties and distortions; a solid, if somewhat degraded, resource base; and the political and social will for reform, a fairly standard recipe of temporary demand reduction, price correction, and trade liberalization should promote sustainable development. However, developing countries in particular may exhibit conditions contrary to the theoretical assumptions underlying structural reform packages: poor infrastructure and undeveloped institutions; insecure property rights; non-enforcement of contracts; severely degraded natural resources (and hence little margin for error in their use); non-existent or extremely thin and uncompetitive markets; grossly inadequate legal and institutional resources to implement even the most basic reforms; or a lack of commitment to economic reform. Thus, macroeconomic reform that is subject to any or all of these complexities may have unpredictable and mixed effects, or may even threaten economic growth and environmental integrity for the future.

Structural Adjustment Programs

A combination of long standing domestic policy distortions and the adverse external conditions of the 1970s (oil shocks, deteriorating terms of trade, debt crisis, and world recession) created severe macroeconomic and structural problems for developing countries ranging from aggregate supply/ demand imbalances to high unemployment and rapid inflation to a shortage of foreign exchange and growing budget deficits. In response to this untenable situation, stabilization and structural adjustment programs were implemented in many developing countries with financial and technical support from international development and financial institutions such as the World Bank and the International Monetary Fund (IMF).

Objectives and Instruments

The stabilization programs usually supported by the IMF had short-term macroeconomic objectives such as reduction in balance of payment deficits, in inflation, and in government budget deficits. The structural adjustment programs focus primarily on long-term objectives such as the diversification of the production base, improved efficiency and increased competition, a shift towards a market system, and rapid economic growth. Over time the distinction between stabilization and structural adjustment has become more blurred as the IMF, World Bank, regional banks, and even bilateral aid agencies collaborated in pursuing a mixture of objectives. While stabilization and sectoral adjustment loans (SALs) have supported economywide reforms, a third kind of policy based lending, sectoral adjustment loans (SECALs), was provided in support of sectoral reform.

The principal instruments of stabilization and adjustment have been currency devaluation, monetary discipline, reduction of public spending, price reforms, trade liberalization, reduction of subsidies, privatization of public enterprises, wage restraints, and institutional reforms, among others.

Assumptions and Economic Outcomes

There are several implicit assumptions in the design and implementation of structural adjustment programs. It is assumed that markets exist and would function fairly well when policy introduced distortions are removed. At a minimum it is assumed that even if markets do not exist for a large set of products, the preconditions and foundations for the emergence of markets do exist. After all, strengthening and more efficient operation of markets is a major objective of the structural reform process. This assumption turned out to be valid in some regions (for example, Southeast Asia) and to be seriously lacking in others (for example, Sub-Saharan Africa). Specifically, secure property rights and enforcement of contracts, two fundamental pre-conditions for the emergence and efficient operation of markets, are seriously lagging in much of Sub-Saharan Africa. Another key assumption is that the country undergoing crisis and in dire need of reform and adjustment has the political and social will to undertake the austerity measures prescribed and to stick to the reforms, despite short-term social and political costs, in exchange for long-term economic benefits. In a number of countries, especially in Africa, the political, economic, and social horizons have been so short that the costs of adjustment loom too large and immediate, while the benefits seem small and distant.

As a rule, where governments were already planning reforms and structural adjustment, external financial and technical support has found fertile ground and has produced the economic outcomes that were envisaged, albeit with significant unforeseen social and environmental by-products. This was clearly the case in countries such as Thailand, Pakistan, and Morocco. In contrast, in countries where the political will was absent, the institutions weak, and the time horizons short, structural adjustment loans were seen as sources of the financial resources needed to respond to the fiscal crisis, while the conditionalities were resented and the reforms not consistently followed, resulting in economic outcomes which were neither planned nor envisaged. The poor performance of structural adjustment programs in much of Sub-Saharan Africa is due to the combined effect of implicit assumptions about markets, institutions, and governments that turned out to be contrary to reality.

Evolution of Social and Environmental Concerns in Structural Adjustment

An inquiry into the environmental impacts of structural and sectoral adjustment policies and programs is a perfectly reasonable exercise in the post-Rio era of recognized economy environment interdependence and sustainable development ethic. It was not always so. When structural adjustment programs first began in the late 1970s and early 1980s as a coherent and identifiable set of economic policies or policy and loan packages, the environment was not even an issue. Not only was environmental protection and management a very low priority, if a priority at all, but no intersection, significant linkage, or spillover between the purely economic policy world of structural adjustment and the natural world was envisaged. Structural adjustment was macro and economic; the environment was micro and non-economic. Economic policies were used to address economic problems; environmental policies could be used to address environmental problems, if it was deemed necessary. The idea that certain development projects such as dams and roads could have significant environmental impacts was beginning to gain credibility among development circles, but the idea that macroeconomic and structural adjustment policies may also have significant and often more pronounced environmental impacts was not just novel, it was alien to economic policy makers and development experts. It was in this spirit of a dichotomous world of pure macroeconomic and structural adjustment that the early adjustment programs were designed and implemented. This was Stage I or the stage of neglect (see Table 3–1).

By the mid 1980s, the social impacts of structural adjustment programs began to assert themselves as the private demand and public expenditure reduction, and other austerity measures had more pronounced impact on the poor and other vulnerable socio-economic groups. It was not that the structural adjustment policies were not accomplishing the economic benefits they had promised, but that the distribution of the short-term costs and long-term benefits was such that those with the lowest incomes and highest rates of time preferences were hit the hardest. For those at the margin of survival, a small rise in prices or fall in social services may make the difference between survival and starvation, regardless of the necessity and long-term benefits of structural adjustment. Thus, the first wave of criticism came from social groups and development NGOs concerned with the social impacts of adjustment programs. This is Stage II or the stage of social consciousness, during which the social impacts of structural adjustment were explicitly recognized though not yet acted on.

Concern with the environmental impacts of adjustment programs followed on the heels of the social concerns but did not relate to them. It came from domestic and international environmental non-governmental organizations (NGOs) which observed that the growth of output and exports stimulated by adjustment policies such as trade liberalization was associated with accelerated resource depletion, especially deforestation and increased pollution. Furthermore, the reduction in public environmental expenditures, as part of the deficit reduction measures, led to reduced enforcement of environmental regulations and a slowdown in reforestation projects, waste treatment facilities, and so on

After a brief period of denial, the proponents of structural adjustment programs admitted the potentially harmful effects of these programs on the environment but they pointed out: (a) that the objectives of these policies and programs were not environmental protection or resource management but macroeconomic stabilization and realignment of the fundamentals of the economy with the new realities of the domestic and world markets to promote economic growth; (b) that structural adjustment programs have several positive environmental impacts, even if not consciously designed to bring them about, through the stability and economic efficiency that they promote (for example, reduction of energy subsidies reduces energy use and environmental pollution); (c) that one cannot pursue several objectives with the same instrument and that structural adjustment is too blunt an instrument for pursuing environmental objectives, which were still seen as micro and largely non-economic; and (d) that any negative environmental impacts can be mitigated concurrently or after the fact with appropriate environmental policies which are parallel, and not integral or even part of the structural adjustment policies. This third stage is that of environmental consciousness during which environmental impacts were recognized but not yet acted on.

While governments and multilateral development institutions have been incorporating environmental provisions and conditions, respectively, in new adjustment programs since the late 1980s, it was not until after the Rio Conference and the worldwide acceptance of the concept of sustainable development that the need for integration of economic and environmental policies became part of the development orthodoxy. Yet, in practice environmental and sustainability concerns remain as add-ons or complementary and compensatory policies rather than becoming fully integrated into macroeconomic and structural adjustment policies. This is the stage of complementary policies (Stage IV), which is the farthest that the evolution of the integration of environmental concerns into structural adjustment programs has reached up to now.

The fifth and final stage of holistic integration of environmental and economic policies in a sustainable development framework remains an ideal that still eludes structural and sectoral adjustment programs, as it eludes economic and development policies in general. One positive sign of further progress is the recognition of the interrelationship between the social and environmental impacts of structural adjustment programs: failure to address the short-term social impacts of structural adjustment (poverty, unemployment, and inequity) may lead to second generation environmental problems of forest encroachment and damage to fragile ecosystems.

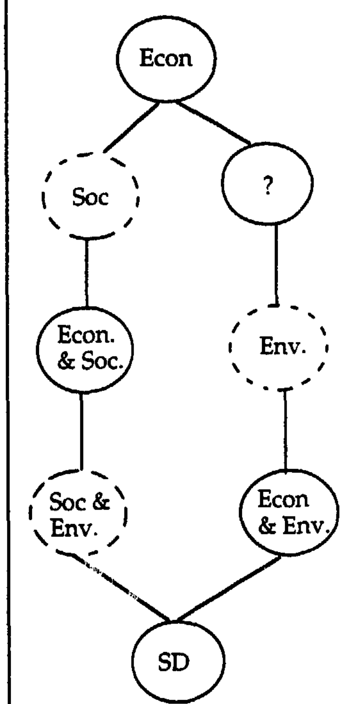
Linking Structural Adjustment and Environment

The links between structural adjustment and the environment are not immediately obvious but complex, multifaceted, and generally indirect. The intervening variables include economic stability and interest rates, growth and structural shifts, employment and distribution, property rights and resource pricing. Furthermore, to establish the linkage it is necessary to quantify and value environmental changes and to establish causal relationships with economic policy changes that are introduced by structural adjustment programs.

A with-and-without rather than a before-and-after framework is needed to weed out the effects of unrelated trends, policies, and external shocks that have nothing to do with

Table 3–1. The Evolution of Environmental and Social Concerns in Structural Adjustment Programs: Five Stages on the Road from Neglect to Integration

Stage	Time period	Progress in incorporating social and environmental concerns in structural adjustment	From pure economic objectives to sustainable development
Stage I	Up to early 1980s	Neglect of social and environmental impacts	
Stage II	Mid 1980s	Social consciousness (social impacts recognized)	
Stage III	Late 1980s	Environmental consciousness (environmental impacts recognized; social concerns incorporated)	
Stage IV	Early 1990s	Complementary and compensatory policies incorporated (to mitigate social & environ. impacts)	
Stage V	By the year 2000?	Holistic integration of economic, social and environ. policies in a sustainable development framework	



Broken-lined circles: recognition but no action.
Solid-lined circles: action
SD: sustainable development

structural adjustment policies except by temporal coincidence or spurious association. Since the environment is impacted through general economic, ecological, and technological interdependence between activities, through intersectoral spillovers as well as price and income effects, determining the environmental impacts of structural adjustment requires a general equilibrium framework with two way feedbacks, from economy to environment and vice versa (see Figure 3–1); not an easy task and, barring a few exceptions, one which has not been done. Most studies that sought to establish and quantitatively assess the linkage between structural adjustment policies and the environment have used a partial equilibrium framework without intersectoral linkage, income effects, and two way feedbacks. While this partial equilibrium approach is made necessary by the lack of data (for example, environmental accounting matrices are rare), the consequence is that the results of such studies are unde-r or overestimates and, in some cases, the reverse of what a more general equilibrium analysis would have yielded.

A further issue concerning the linkage between structural adjustment and the environment has to do with the implementation gap. Since structural adjustment policy prescriptions and conditionalities are rarely observed as agreed upon or intended, it is often not clear whether the identified environmental impacts are due to the prescribed policies or to their incomplete implementation. This is particularly important since structural adjustment policies are designed as a package of complementary, compensatory, and mutually reinforcing policies; a partial, selective, or incomplete implementation may result in greater or smaller environmental impacts than the full package of policies depending upon which parts were dropped or were not fully implemented. Similarly, failing to follow the prescribed sequence of policy reforms may result in radically different results than intended or anticipated. For example, if the need for improved security of property rights was recognized before trade liberalization, but because of institutional delays it was postponed, the effects of trade liberalization on deforestation and natural resource management would be different from those anticipated.

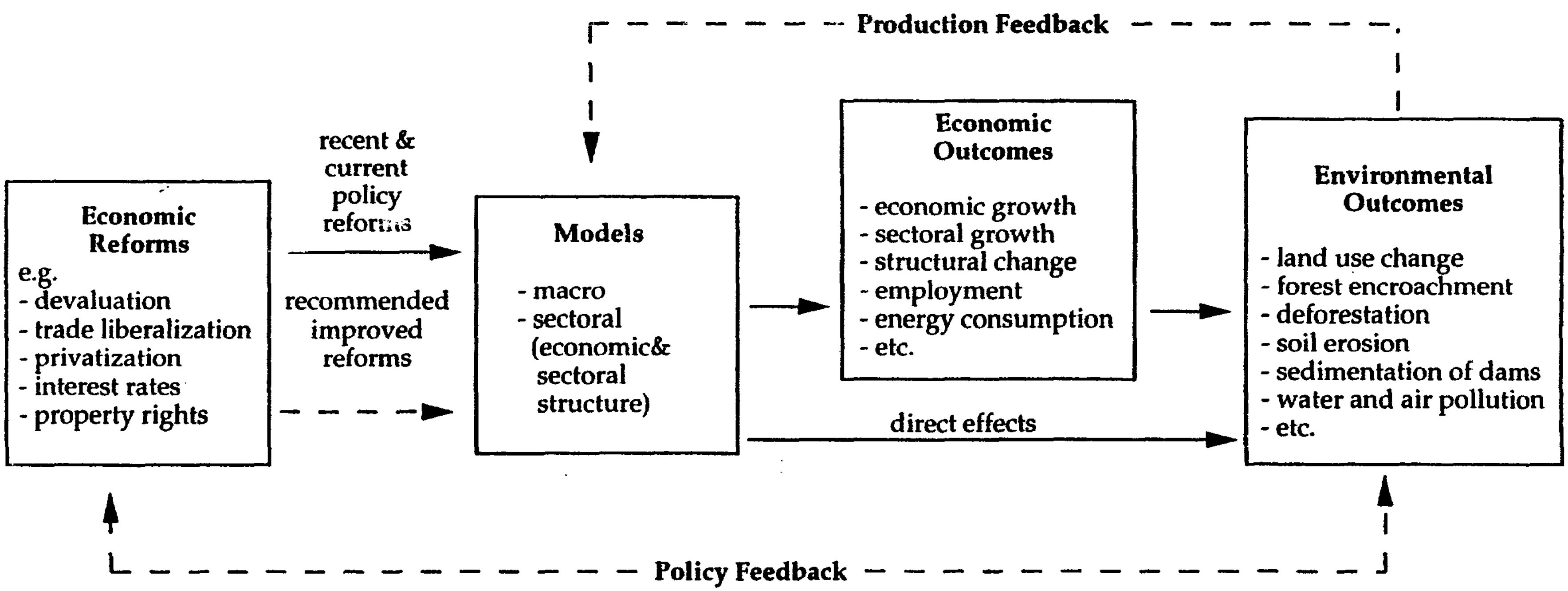
While there are serious difficulties in both anticipating and after the fact tracing and attributing the environmental impacts of structural adjustment policies, the problem with most adjustment programs, especially the earlier ones, has been the failure to consider such effects at all or the tendency to make implicit assumptions about their likely significance and mitigation by nonexistent or poorly enforced environmental policies. For example, a recent study by HIID/WWF of five countries (El Salvador, Jamaica, Pakistan, Venezuela, and Vietnam) concluded that in none of the countries studied had the environmental impacts of the reform programs been considered in the design or implementation of the reforms — not even when consideration of environmental impacts might have provided additional justification for the reforms, for example, in the case of reducing fertilizer and pesticide subsidies. SAL I (1991) in El Salvador did not make a single reference to the environment. The first explicit reference occurred in the appraisal report for SAL II in September 1993. In Venezuela and Jamaica the structural adjustment programs contained no explicit supposition as to their likely impacts on the environment in contrast to their explicit consideration of the social impacts and the provision for compensatory social programs. In the case of Pakistan, while the environmental impacts of reforms were equally ignored, World Bank documents related to structural adjustment programs acknowledged the limited objectives of adjustment programs and called for compensatory policies in the social and environmental areas.

In conclusion, environmental concerns have not played a major role in either domestic economic reforms or official development assistance, the implicit assumption being that environmental impacts are either minimal or can be cushioned by supplementary or parallel environmental policies, even though the latter are only slowly being put in place and even more slowly, or selectively, being enforced. A most damaging implicit assumption in many structural adjustment programs relating both to economic and environmental outcomes is that secure property rights over resources are either in place or do not matter. There are important exceptions however, such as the US$30 million side loan provided to Thailand by the World Bank to undertake cadastral surveys and land titling in support of the structural adjustment programs of the early 1980s.

The State of Knowledge

Much of the non-economic literature recounts disastrous environmental side effects from structural adjustment programs (SAPs), including deforestation, increased pollution, and general overexploitation of

Figure 3–1. Environmental Impacts of Structural Adjustment with Production and Policy Feedbacks



non-renewable and renewable resources in response to export biases and changes in the political economy. Much economic analysis also recognizes these trends, but avoids such unambiguous attribution.

During the 1992 International NGO Forum on World Bank and IMF Adjustment Lending, three major themes emerged concerning the impact of SAPs on natural resources: (a) stabilization measures usually exacerbated economic conditions for the poorest segments of society, forcing them to overexploit natural resources that were available to them and to move on to marginal lands; (b) the trade liberalization of structural adjustments and orientation toward the primary commodity export sector has increased rates of deforestation, soil erosion, desertification, and water pollution; and (c) sharp reductions in public expenditure have often entailed a shrinking of the environmental protection apparatus and institutions — including enforcement capacity. Together, these trends imply environmental deterioration within and outside formal markets and a public sector that is handicapped to address the problem.

Many economists argue that, while all the above trends may have been documented, the causality is inconclusive and the generalization unwarranted. In addition, the large body of evidence showing positive environmental impacts from economic reform is entirely ignored. These successes include the removal of perverse subsidies that encourage waste or over-intensive resource exploitation, the introduction of stability which promotes sound resource management and lower marginal time preference, higher living standards which may entail increased demand for environmental quality, and general efficiency and technology gains.

In order to sort out these divergent viewpoints, it is necessary to review the body of case studies and analyses that focus on the above issues. We have attempted to gather together a (hopefully) representative group of studies for this purpose. They are included in the attached bibliography, along with some background information on adjustment programs and developing country environmental problems in general. In addition, a matrix of case studies is provided, which attempts to break down the temporal, geographic, methodological, economic, and environmental components of each study. The findings are summarized generally and selectively, conclusions not directly relevant to this inquiry are often omitted.

The foci, assumptions, and conclusions of the selected studies are widely divergent and sometimes at odds, but some general relationships (which will be covered in the next section) and commonalties emerge. From the work thus far completed, we have distilled four key observations:

1. Market reforms should increase efficiency of resource use and promote a welfare enhancing allocation of both productive assets and consumption goods, but this only holds for traded market goods and factors operating within efficient markets. Failure to recognize this simple truth can lead to net economic losses, serious resource degradation, and, most assuredly, unpredictable results from reform.
2. In order for market reform to serve non-market needs, it must account for or internalize the environmental and social externalities of economic activity. This is problematic, since environmental goods and services, as well as social needs, are not always easily amenable to quantification and measurement. Where market internalization is possible, for example through securing property rights, shadow pricing, subsidization of positive externalities, Pigouvian taxation of negative externalities, emissions trading, and so on, it is a preferable means of correcting market failure. Where impossible, non-market command-and-control policies

must be coordinated with reforms to achieve the desired economic, social, and environmental outcome.

3. None of the above strategies will yield predictable results unless the appropriate institutions exist to communicate incentives, information, control, and enforcement. Structural adjustment without attention to capacity building and institutional reform amounts to little more than a reform gesture, and may in fact do more harm than good.
4. Similarly, environmental outcomes from economic reforms depend to a large extent on how well economic and environmental policies were integrated prior to the reform process.

Review of Selected Studies

While the structural adjustment era (mid 1970s to present) initially failed to address environmental issues adequately, it is evolving to integrate the environment more broadly and with more depth, as environment economy interactions manifest themselves over time and as both the developed and developing countries develop greater awareness of the productive capacity and inherent value of the environment. A quick overview of studies on the subject underlines just how new and how rapidly growing are the multilateral development banks' (MDBs') concerns over structural adjustment's environmental implications.[1]

Initial inquiries into this field include Hansen's (1988) "Structural adjustment programs and sustainable development," which chronicles early efforts between the World Bank, IMF and host countries to explicitly address natural resource management in SAPs, making recommendations for broader and more economically integrated natural resource elements. At that time, only a quarter of the Bank's Asian and African SALs even mentioned the environment, and far fewer included relevant policy measures. Sebastian and Alicbusan's (1989) chapter, "Sustainable development: issues in adjustment lending," further develops the conceptual framework of economy environment linkages, explores the expanding environmental elements of SAPs, and includes more coverage of institutional and policy issues. It found that, while environmental issues were mentioned more often in SAPs, specific policy measures to address them were still lacking.

In 1994, Warford and others provided a comprehensive review of "The evolution of environmental concerns in adjustment lending," with three country studies and deeper analysis of environmental social economic interplay. At this time, an estimated 60 percent of adjustment loans addressed environmental issues at least partially, and two stand-alone environmental adjustment loans had been initiated. Complementing this study was the Munasinghe and Cruz (1994) World Bank monograph, *Economy-wide Policies and the Environment: Emerging Lessons from Experience*, providing case studies of eleven countries and similarly more sophisticated analysis of linkages and interdependence.

Major findings of these studies are included in Matrix Two and are integrated into the discussion in the next section. A broad argument made in Munasinghe and Cruz (1994) and Warford and others (1994) seems to apply to most of the theoretical economic discussions of environment and adjustment. In brief, the impacts of adjustment programs are difficult to predict, especially in the environmental area where imperfections (such as market failures, policy distortions, and institutional constraints) abound and where economy-environmental linkages are poorly understood. Therefore, specific complementary measures are required to address such imperfections that give rise to the adverse environmental and social impacts of adjustment programs. Where possible, it is more desirable to implement such complementary policies in tandem with (or as part of) adjustment reforms rather then ex post.

The above studies all concluded that the net effects of SAPs on the environment are positive, although programs should be tailored more appropriately to meet environmental needs in the future. Sebastian and Alicbusan (1989) noted that much of the economic and environmental crisis now evident in host countries stems from debilitating external shocks in the late 1970s and 1980s, and that rapid population growth continues to thwart any improvements in standards of living in most developing countries. They stress the need for complementary measures to address the informal sector and the environment, recognizing that market reform alone is not directly attacking all environmental problems. Nonetheless, they do assess net positive environmental impacts and even find "no evidence to connect adjustment policies with significant environmental damage." Much of this assessment is based on assumptions about the future efficiency of markets and institutions within host countries and on the expectation that appropriate internalization measures will be eventually undertaken. For instance, one reason for environmental optimism is that SAPs "enable economies to internalize (and reduce) the social costs of environmental degradation." Enabling, however, does not imply effecting internalization, and there is little evidence that developing countries are undertaking comprehensive efforts to effectively internalize environmental or social costs.

Hansen (1988) also found it "obvious that conventional adjustment programs [...] hold the potential to provide efficient instruments for the integration of environmental and natural resource concerns in development activities," but stressed that the "challenge is to convince the decisionmakers involved that proper adjustment programs require adequately addressing and reflecting current environmental concerns. This requires adoption of multi disciplinary analytical approaches and calls for an active cooperation between the different agents in the development planning system." In addition, he cautioned that MDBs ought to recognize their imposing stature when dealing with poor, vulnerable nations and take special care to elicit from host country negotiators their development goals, avoiding an imposition of their own. These points notwithstanding, Hansen assesses net positive environmental effects and even better potential impacts from structural adjustment and stabilization programs.

Reference to Matrix Two highlights the many different conclusions drawn as to net environmental effects of adjustment. Most of the literature that leans heavily on a political or sociological perspective (for example, International NGO Forum) tends to focus on negative outcomes, whereas the more economics-oriented analyses (for example, WWF collaborative studies) find mixed or ambiguous, and occasionally, positive net environmental outcomes.

In Matrix One, the potential impacts of macro reform are summarized in terms of three sectors: the formal sector (that is, the monetized market economy), the informal sector (which includes household production, subsistence agriculture, the non-cash economy, and so on) and the natural sector[2] (which includes all environmental goods and services, non-human production systems, and so on). By attempting to separate out the impacts among the three sectors, it seems evident that the net economic and environmental effects of reform depend on how carefully the informal and natural sectors are considered in adjustment packages.

Synthesis of Findings

Some generalizations on economy environment linkages are offered above, and most are ultimately ambiguous as to net positive or negative environmental consequences of a given policy action. Where the generalizations have been asserted unambiguously, they are usually based more on economic theory than on empirical evidence.

A closer look at the country studies reveals that ambiguity reigns at the aggregate level due to differing, sometimes contradictory, findings among different research projects.

Observing how and why the results may differ from study to study will probably yield more insight into the complex economy environment linkages than trying to formulate generalizable aggregate relationships. The majority of divergence in study findings can be grouped into three contexts:

1. Site-specific differences,
2. Difference in research assumptions, and
3. Differing depths of analysis.

Site-specific Differences

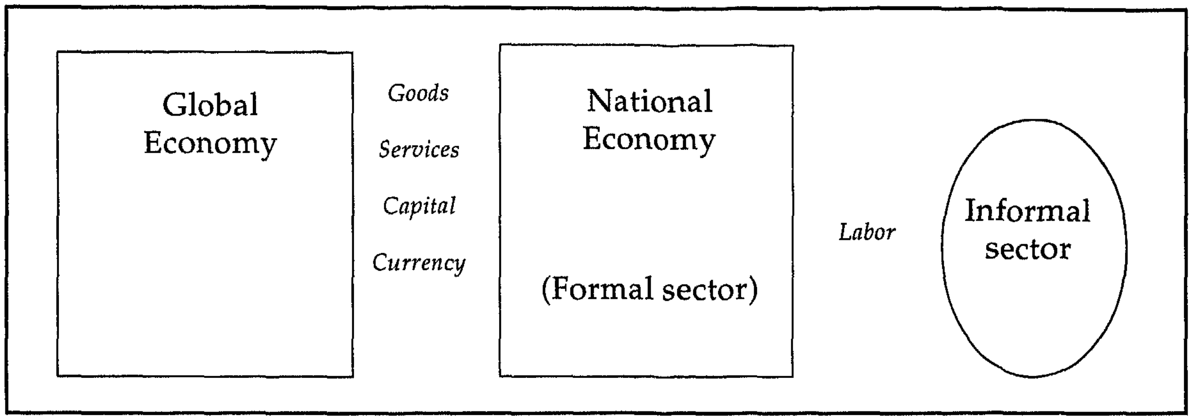
Each nation's development context is different in terms of culture, politics, resource base, climate, and so on, and analyses of the effects of a similar policy initiative may yield far different results according to this context. For example the promotion of tourism is found to have different implications for the environment in Jamaica, Thailand, Zimbabwe, and Tanzania due to different regulatory regimes, foci of tourist promotion, and levels of ecosystem fragility. Jamaica's tourism promotion concentrated on its comparative advantage of beach leisure activities, but inappropriate coastal zone management and high levels of tourist visitation have led to severe erosion, coral reef and estuary damage, and waste problems (WWF/HIID 1994). Thailand's promotion of tourism has involved similar problems in beach areas (for example, mangrove destruction and coastal damage from development), but the growth of tourism has also reduced the level of many harmful agricultural practices indirectly, yielding positive environmental outcomes (Panayotou and Sussangkarn 1991). In Zimbabwe and Tanzania, on the other hand, tourism has focused more on managed wildlife, providing incentives for conservation of habitat and species. Even in these African countries, where tourism may concentrate on ecosystems arguably less fragile than estuaries and reefs (that is, semiarid rangelands), the net ecological damages vary according to the tourist load, the methods of wildlife management (for example, pristine, culled herds, and so on), and the regulatory framework surrounding tourist services (Muir, Bojö, and Cunliffe 1994; WWF/ODI 1994).

Different Conclusions Arising from Research Assumptions

Conclusions on net environmental effects of economic policy will vary even more according to the assumptions, implicit or explicit, underlying the analyses. For example, increased stumpage prices are generally presumed to stem deforestation, since the cost of commercial timber extraction becomes greater. Persson and Munasinghe (1995), using a general equilibrium model that included property rights simulation, found that increasing stumpage prices in Costa Rica may have actually promoted deforestation due to a shift toward agricultural production, entailing forest conversion. This unexpected result may not have been discovered had a partial equilibrium model been used (implicitly assuming no changes transmitted through other sectors).

Similarly, it is possibel to argue that energy price increases may not have a net positive effect on the environment through reduced use and pollution. A change in the relative price of fuels may make coal a more desirable an input than oil, implying higher pollution per unit of output. Even across-the-board price increases for all commercial fuels may have net negative impacts if people respond outside the formal market by switching to fuelwood (leading to increased deforestation) or by burning dung, crop residue or peat (leading to reduced soil productivity). The crucial assumptions in the latter case involve secure versus insecure property rights and the existence—and therefore behavioral responses—of a significant informal sector.

Figure 3–2. Relationship among the Global Economy, National Economy, and Informal Sector



DIFFERENT DEPTHS AND BREADTHS OF ANALYSIS

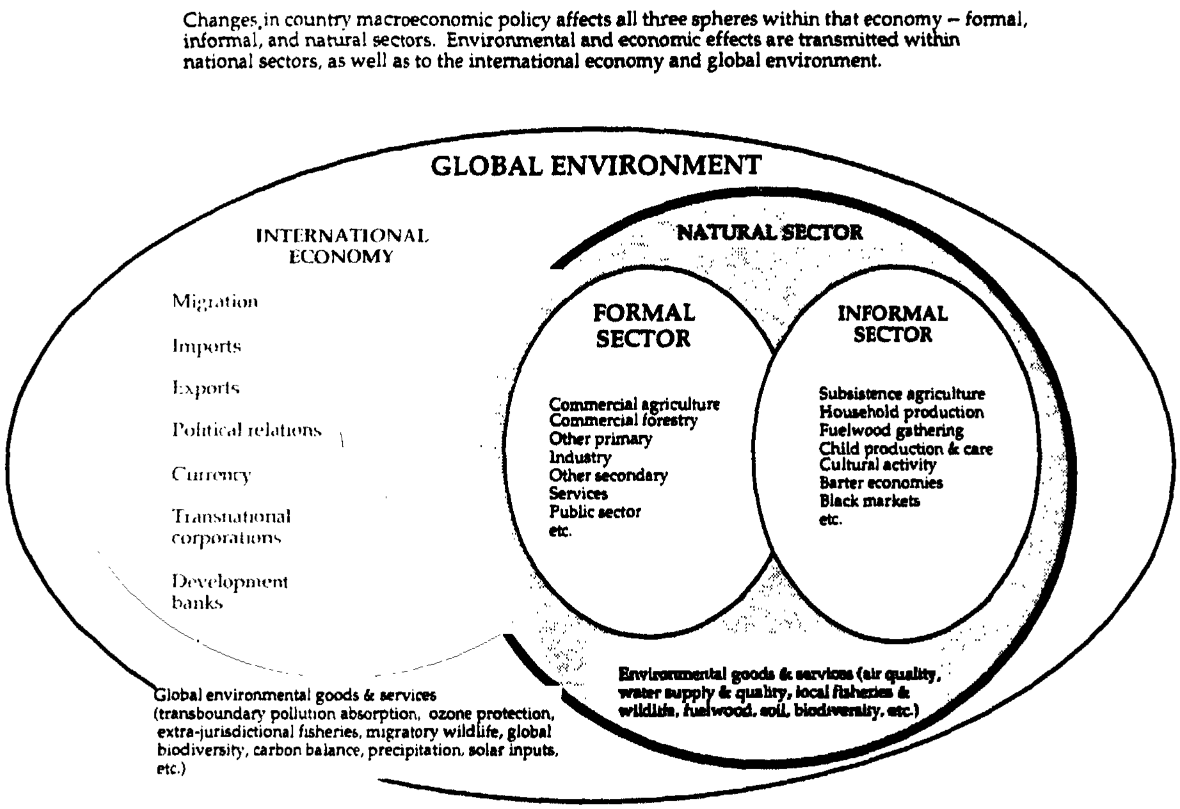
Conclusions are also highly dependent on the depth and breadth of investigation into environmental consequences. Soil erosion, for example, is often said to increase as a result of increased agricultural exports from trade liberalization (as in the several country summaries from the International NGO Forum 1992). This conclusion seems to be based on the broad observation that soils were depleted as export agriculture grew. Many of the World Bank studies (for example, Hansen 1989) argue that soil erosion may increase or decrease depending on the root structure and common management practices of the type of crop promoted (based on Barbier 1988). An even deeper analysis of the erosion trade relationship is provided in Barrett 1992. This study finds that the incentives and preferences of individual farmers toward soil conservation may differ widely, even under similar economic circumstances or crop choices; thus trade reform will have highly variable, unpredictable effects on rates of soil erosion, even if preferred crop types are known.

Differences in the depth and breadth of analysis introduce biases toward theory, observation, and empirical analysis, as well as the level of aggregation. As with research assumptions and site specificity, we find results that sometimes conflict with each other. In the next section, we explore a conceptual framework that may help researchers to sort out these conflicts and may, at least qualitatively, bring the analysis closer to discerning what environmental outcomes are likely to result from economic reforms.

Methodological Critique

Traditional conceptual models of macro policy effects seem to assume well-defined and functioning formal sector trading goods, services, and capital with the rest of the world. Some recognize an informal sector in the economy which primarily absorbs or supplies labor to the formal sector (See figure 3–2). Most of the studies covered in this chapter expand upon the above framework by including some environmental variables and discussing either formal or informal sector impacts on these variables that arise from changes in macro policy. Most commonly analyzed are soil erosion, deforestation, and different types of pollution. It is important to recognize, however, that the environment cannot adequately be represented by one or two variables; that formal sector environmental impacts may be offset or overshadowed by informal sector environmental impacts; that the environment itself affects production

Figure 3–3. Conceptual Model of an Economy
(The individual economy is bounded by the bold line)



and consumption patterns in these sectors; and that there is a constant interplay among national and international environment and economy. In short, a more holistic approach is required.

A potential new framework for analyzing the environmental implications of macro policies might account for the formal, informal, and natural sectors, recognizing that net impacts depend on the interplay of these sectors. The three major arenas in which the consequences of reform play out could then be defined as:

1. Formal sector interactions,
2. Formal-informal sector interactions, and
3. Formal-informal-natural sector interactions.

These three sectors are interdependent and also tied to the international economy and the global environment. Conceptually, these relationships are represented in Figure 3–3. Viewed from this vantage point, the impacts discussed in Matrix One may be better understood. First, structural shifts will occur within one arena, say the formal sector, and have direct implications on activities in the informal sector. The net impacts flow out to the natural sector, which responds through a change in the structure and level of environmental goods and services for consumption or productive input in both formal and informal economies.

Second, feedback loops occur between the environment and other sectors of the economy. Most of the literature deals specifically with macroeconomic impacts on the environment, not explicitly recognizing that subsequent environmental impacts on the macroeconomy may be just as important to a nation's development and future welfare.

Third, it cannot be understated that efficient markets and effective institutions are vital to achieve the desired outcomes from reform. Markets and institutions are essential to harness the powerful forces of economic reform, just as a dam is essential to harness the power of a river. To use the analogy of a hydroelectric dam (particularly relevant to MDB project lending), the flow of water can be a source of energy to fuel the development of downstream communities. If the flow were to increase drastically or suddenly, it might break the dam and inundate the communities. If the dam was barely large enough to begin with, any increase in flow cannot be harnessed, and it may cause trouble downstream. In addition, more energy might be generated through more efficient generators with or without an increase in water flow.

The "Ideal" Case Study

Given the complexities of the conceptual model, current quantitative methods of inquiry would be stretched to the limit to cover all the bases listed above. How might a country case study best address the issue?

The ideal case study would measure the environmental outcomes of individual reforms against the hypothetical environmental consequences of maintaining pre adjustment policies. This with-and-without approach will grant far more helpful results than a simple before-and-after approach, which ignores all intervening factors. For example, most of the literature criticizing adjustment decries continuing or worsening economic disparity and poverty after SAP policy implementation. While these observations are well founded, they should be compared to conditions in those countries which did not undertake adjustment programs, for which the OECD estimated a 20 percent decline in income for the poorest of the poor (Stackhouse 1994).

The ideal study would also account for formal sector and informal sector responses to policy, and it would recognize feedbacks from natural systems.

Before-and-after comparisons, partial equilibrium models, general equilibrium models that fail to fully integrate social and environmental factors, theoretical analyses, and historical narrative accounts all fail to meet these ideal criteria and thus can provide no unequivocal evidence of effects that are solely attributable to structural adjustment policies. As with any other field of research, we are left with ambiguous conclusions or unambiguous conclusions that are biased by the normative assumptions of the researchers.

Methods and Models

In the matrix of studies (Matrix 2), the research methods employed are broken down into some basic categories, including:

- Historical (discussion of events, consequences, and intervening factors),
- analytical (implying that quantitative models or calculations were used, but the method is unspecified),
- case studies (integration of site specific research projects), and
- various models such as partial equilibrium (PE), computable general equilibrium (CGE), linear programming (LP), and social accounting matrices (SAM).

Reliance on one particular quantitative methodology may yield very precise results, thus edifying many theoreticians or policy analysts. But to what extent might this precision be at the expense of accuracy? Accurate determinations may require consideration of all sorts of historical, exogenous, and external factors not formally addressed in a given analysis. In short, they may involve a great deal more uncertainty or suggest a number of safe and preferred policy choices, rather than a singular optimum. It is for these reasons that not only should models attempt to integrate a large number of significant factors, but also findings and recommendations should balance the insights drawn from different models and from historical or otherwise qualitative analyses.

Among the quantitative models, multi sector computable general equilibrium models seem to yield more insight than partial equilibrium models, which is to be expected given that adjustment processes manifest themselves primarily in interactions among sectors. Even the CGE's, however, fail to represent all the productive sectors of the economy, which would include the environment and informal sector. True, rudimentary environmental accounting matrices and non-tradable resource sectors have been integrated into some of the general equilibrium models, but insufficient data and conceptualization difficulties preclude a holistic, representative model.

Girma 1992 presents an almost ideal analytical framework to model structural adjustment's social, environmental, and economic ramifications — integrating macroeconomic dynamics, microeconomic behavior, social variables, and an environmental sector (representing environment as both a productive asset and a consumption good in its own right). To the authors' knowledge, such a holistic quantitative effort is as yet in the theoretical stage and has not been applied to any real world economy. One reason this is true is that the framework lacks empirical data to support it. Conceptual models of economy environment linkages all seem to begrudgingly admit this caveat somewhere in their discussion.

Too often, quantitative models yield intriguing results which are internally consistent but do not reflect actual events in the economies they presume to simulate. Better put, they corroborate the assumptions and underlying coefficients chosen for the model such as, for example, assumed inelastic supply functions yield inelastic supply responses in various policy scenarios. Certainly, more empirical analysis on the true function (that is, not a fixed number) of the various coefficients is warranted.

Given modeling limitations such as these, the anecdotal evidence, survey data, case studies, and historical analyses served well to complement the model results, fill in gaps, or sometimes challenge the model's conclusions.

Some methodological "reality hurdles": exogeneity, stochasticity, and external distortions

Market, policy, and institutional failures within host countries are not the only reality hurdles that models and theory must deal with. Exogenous, stochastic, and external factors abound that threaten the sustainability of development strategies promoted by structural adjustment lending.

The quintessential exogenous factor, with particular relevance to agrarian economies, is weather. How well do SAPs protect a nation's development vector in the presence of unforeseen droughts, floods, or other natural disasters? For example, Zimbabwe experienced a serious drought in 1991-92, just at the beginning of its economic structural adjustment program implementation (Eakin 1994). Adherence to loan conditionalities, namely the export orientation of food crops such as maize, took precedence over the need to feed citizens starving as a result of the drought. Drought mitigation measures took place only after the loan was secured in February 1992.

Two strategies may mitigate these potential crises. First, quantitative models that venture to determine the appropriate allocation of resources for human and economic development may be subjected to stochasticity. Thus, for example, the appropriate shares of grain production for export or local consumption would depend upon the overall production that year, which would depend in part on a stochastic precipitation variable. In fact, the integration of climate forecasts and other environmental data may reduce the level of uncertainty.

Second, and perhaps more important, any adjustment program should contain provisions for unforeseen events. In the drought example, it might allow for temporary subsidization of grain distribution locally or temporary re-orientation of grain marketing to favor local consumption. If food shortages are likely to occur with regularity, a small level of food security protection might be justified.

Third, external market distortions should be considered. For instance, does the liberalization promoted in SAPs rely on hypothetically free global markets or on the actual conditions of the global market place? Of particular relevance to this question are the terms of trade between developed and developing countries. Nigeria, for example, expressed concern to the 1991 GATT council that five years of SAPs had failed to adequately diversify Nigerian exports, owing primarily to the import restrictions of developed countries (Iheduru 1992). Essentially, the unilateral liberalization on Nigeria's part mostly boosted oil exports to developed countries. The extent to which adjustment capitalizes on Nigeria's comparative advantage in a global market is clearly dependent on the North's revealed commitment to free markets.

Other exogenous factors that will negatively distort a country's adjustment and development, particularly with regard to the environment) are global commons issues (for example, extra jurisdictional fisheries, global warming, transboundary pollution), migration patterns, balances of power (for example, developed and developing and inter-developing countries), and, perhaps most significant, war. Admittedly, no model could adequately factor in, much less predict, all these phenomena, but some methodological advances could be endeavored. More importantly, these factors should be considered qualitatively and conceptually when SAP agreements are formulated.

In summary, even if host country failures of market, policy, and institutions are accounted for, structural adjustment requirements based on assumptions of a predictable world and non-distorted world markets will not necessarily promote sustainable development in developing countries. For example, the whims of nature or the existing policies of the developed countries could have worse consequences for human welfare or natural resource use if inappropriate adjustment policies are adhered to. For these reasons, SAP agreements and the analyses thereof should:

1. Contain provisions for potential stochastic shocks,

2. Account for external market distortions (that is, not assume a level playing field), and where possible, include external and stochastic parameters in their models.

Failure to qualify agreements or adjust calculations in this manner may overshadow or even nullify the welfare and development gains promised, and predicted, by structural adjustment.

Needs for Further Research

Dynamic models need to be developed that represent a true general equilibrium, including comprehensive social and environmental accounting. Feedbacks are crucial, as the natural resource systems affect development as much as development policy affects them.

Empirical research should be undertaken to determine true, variable elasticities and coefficients. Fixed, assumed coefficients appear to do little more than corroborate the research assumptions made in setting them — typical "begging the question" reasoning of poor economic analysis.

Efforts should be made to determine realistic assumptions about the global marketplace, the uncertainty of political and natural dynamics, and other exogenous and external factors affecting development.

Above all, data are required on environmental phenomena and the intervening social, demographic, and biological variables. Where quantitative measures of important variables are unavailable, normative goals must be set. Lack of amenability to quantification does not imply lack of importance. Development of environmental accounting matrices that can be combined with social accounting matrices to build truly general and dynamic equilibrium models with two way feedbacks between the economy and environment are both necessary and feasible at this stage of development of the interface between structural adjustment and the environment.

Conclusions and Policy Implications: Integrating Environment and Sustainable Development

Environmental improvement has not been an aim of structural adjustment policies in the past and therefore it is not fair to use an environmental measuring rod to judge such policies, especially with the benefit of hindsight. However, to the extent that such policies lead to natural resource depletion or environmental damage beyond the economic optimum, they are defective in economic terms, that is, they fail their very own objectives. Furthermore, with the growing realization that the environment cannot be divorced from economic development, future structural adjustment policies need to not only be explicit about their environmental implications, but also to treat the natural resource base and the environment as economic assets in the same way that man made capital is treated. For only then would stabilization and structural adjustment policies take their rightful position, not only as preconditions but also as agents of sustainable development. It is in the context of designing and implementing improved structural adjustment programs in the future that the assessment of the environmental performance of past programs has been undertaken.

A number of conclusions and policy implications emerged from the survey and attempted syntheses of the findings of the studies on the interface between structural adjustment and the environment. Some apply to the studies themselves and others to the design and implementation of future structural adjustment programs. Box 3–1 proposes some further guidelines towards improved structural adjustment programs.

Implications for Studies

1. When assessing the overall impact of structural adjustment and related economywide reforms on the environment, it is necessary to go beyond the first round of impacts and analyze the responses of people and natural systems to these impacts and indeed, to trace the path of adjustment.
2. The relevant comparison when assessing the environmental and social impacts of macroeconomic and structural reforms, as indeed with any policies and projects, is not between the situation before and after the reforms or programs but with and without them, and this necessitates the controlling of many other factors and policies that contribute to the apparent outcomes. This in turn requires the collection of benchmark environmental conditions at the time of the first introduction of these programs and the reconstruction of the without scenario, against which the with scenario can be compared.
3. The environmental impacts of structural adjustment programs and related economic reforms needs to be valued in economic terms, using the valuation methods for both market and non-market goods and services, and be fed back into the economic system in order to fully capture the general equilibrium effects in a dynamic context. In a dynamic CGE formulation, the feedback mechanisms are imbedded, with a lag, in the produc-

tion and utility functions to affect economic output and social welfare by changing the productivity of inputs and the utility of outputs. However, by definition any environmental impacts that are worth averting or mitigating cause excessive damage — that is, reduce economic output and welfare by more than the cost of potential remedy — and therefore, unless they are explicitly modeled, it is not possible to determine the optimal level of intervention that will maximize economic output or social welfare by equating the relevant marginal costs and benefits.

4. Studies of the interface between structural adjustment and the environment should not be limited to the linkage between the formal sector and the environment but they must explicitly model the informal sector and its two way linkages with both the formal sector and the natural sector or the environment in its broadest sense. This is not only because the informal sector, which operates largely outside the market economy, has pronounced impacts on the environment. It is also, and perhaps more importantly, because many of the impacts of structural adjustment programs that operate largely in the realm of formal sectors and markets are often magnified and transmitted to the environment through the informal sector whose activities, though not market-oriented, are indirectly but profoundly affected by economic and market reforms.

Implications for Structural Adjustment Programs

1. The question is not whether or not to undertake structural adjustment but what kind of structural adjustment, at what pace, and with what reform sequence. Tailoring and fitting structural reforms to the specific condition of the host country is something that was done poorly, especially as it concerns Sub-Saharan Africa where there was only limited recognition of the fundamental differences from, for instance, Southeast Asia, especially with regard to the role and efficacy of embryonic markets.
2. Structural adjustment programs must pay as much attention to market and institutional failures as they pay to policy failures. Otherwise, the gains from correcting one failure may be lost by exacerbating the other. Recognizing their second-best nature structural adjustment programs must provide for a carefully thought out and designed sequence of consistent and mutually reinforcing reforms that can bring the economy closer to the optimum on all fronts, not just in a narrow set of objectives (for example, openness of the economy, competition, privatization) which are not social goals in themselves, only the means to a higher ends, such as improved social welfare.
3. Using environmental and social policies as add-ons or supplementary and compensatory or parallel policies, to mitigate or cushion the environmental and social impacts of structural adjustment, is second-best to the full integration of these policies with the economic reforms in the context of a sustainable development strategy.
4. Structural adjustment programs can best ensure sustainability by providing for reinvestment of rents from the depletion of natural resources in natural, environmental, man made, and human capital to maintain and expand the productive capacity of the economy and the quality of life. In the absence of secure property rights over natural resources and the lack of internalization mechanisms for externalities, structural adjustment policies such as currency devaluation, trade liberalization, and privatization may lead to net disinvestment of natural and environmental capital without commensurate formation of other forms of capital, a

necessary, though not a sufficient, condition for ensuring sustainability. Where the first best policy of establishing secure property rights and internalizing externalities cannot be accomplished, imposition of the extended Hartwick rule of sustainability (reinvestment of resource rents) can prevent disinvestment during the adjustment process.

5. Partial reforms or incomplete implementation of reforms may do more harm than good if they are selectively applied to benefit certain constituencies without due regard to their social and environmental impacts. The selective implementation of structural adjustment programs reduces their economic effectiveness without necessarily reducing their social and environmental impacts. Again, holistic integration of economic, social and environmental policies in the design of structural adjustment programs is the best insurance against piecemeal and selective implementation.

In conclusion, international development assistance institutions, such as the World Bank and the IMF, have a critical role to play in promoting sustainable development by insisting on and assisting in the holistic integration of economic, social, and environmental policies in their stabilization and structural and sectoral adjustment programs, and other development assistance they provide. The missed opportunities of the past should serve as valuable lessons for the future. Dwelling in the assignment of blame for past failure, with a great deal of hindsight, has high opportunity costs in terms of the forgone consensus for the design of better programs and policies in the future, in the interest of sustainable development to which both the development and environmental communities subscribe.

Notes

1 It is vital to note that MDB involvement in environmentally relevant projects, capacity building, and policy extends far beyond the scope of SAPs. While not explicitly tied to SALs, SECALs, and other stabilization or adjustment packages, these endeavors most certainly influence the development vector of host countries. The reader is referred to such publications as *The World Bank and the Environment*, published annually, among other valuable sources of data on environmental projects and policy in multilateral lending.

2 Natural resources and the environment are often referred to in the literature as natural capital or natural assets, not as the natural sector. The latter term is chosen here to stress that the natural world and resources underlying both formal and informal sector activities are an integral, dynamic, and productive part of the economy. While goods such as timber or minerals serve as extracted inputs for the other sectors, services such as pollution absorption, flora and fauna production, ecosystem services, and the very root of life energy (solar radiation) are not choices but absolute necessities for the economy to function. "Sector" thus may even be an understatement.

Box 3–1. Towards Structural Adjustment Program Guidelines

Based on the findings of the studies we have reviewed and our own analysis, we would propose the following guidelines for adjustment program planning and implementation:

Structural adjustment programs, or autonomous reform decisions, should be based on knowledge, not only of the dynamics of the formal economic sectors, but of the informal sectors of the economy, such as subsistence agriculture, barter economies, indigenous peoples' social and resource practices, and household non-market production. Elements of these informal sectors which are destructive (for example, swidden agriculture, open access exploitation, or inefficient energy use) may be targeted for reform, whereas neutral or beneficial elements (that is, sustainable or socially beneficial practices) should be shielded from adverse adjustment effects.

In addition, the natural sector of an economy must be recognized, such as plant and animal communities or ecological services — none of which really respond to policies directly but rather are impacted unidirectionally. Normative decisions must be made as to which elements are to be preserved and to what extent. These decisions must be made in advance of macro policy decisions that impact the resources; otherwise policy effects may be unnecessarily expensive (for example, pollution cleanup) or irreversible (for example, species loss). Uncertainty as to the potential benefits of the resources and costs of their loss should introduce a bias toward conservation.

After the above determinations have been made as to the informal and natural sectors, adjustment policies should be sequenced as follows:

1. Stabilize welfare of poorer segments of society. Rather than setting goals of per capita income levels, which imply nothing in terms of equity, set goals of actual incomes for poor families in the formal sector and of actual welfare proxies (health, nutrition, rights) of poor families in the informal sector. Examples might include promoting labor intensive agriculture, artisanal activity, services, and labor intensive manufacturing. Account fully for the environmental and social consequences of economic activities favored by the reforms.
2. Reform ë75 s and institutions that facilitate efficient markets. Set environmental and social goals alongside economic goals, and ensure that the capacity and infrastructure are present to maintain these goals in the presence of free market forces. For instance, provide that: land tenure can be secured for smallholders or poor families, resource rents can be effectively monitored, taxed, and reinvested and effluent limits can be enforced.
3. Investigate what potential or fledging economic activities would have a comparative advantage in international trade. Develop and expose these activities gradually but steadily to greater international and domestic market discipline. Simply opening the floodgates of trade may never lead a nation to exploit its comparative advantage, if its initial access to capital, technology, and expertise lags far behind that of its competitors. This may explain the often inefficient and unsustainable exploitation of developing country primary resources that has resulted from too rapid transition to free trade.
4. Gradually adjust energy and resource prices to reflect non-market costs. The tradeoff between economic activity and external costs, where these cannot be valued and internalized, will be determined in large part by normative decisions on allowable losses in the natural sector.
5. When vicious cycles of poverty and environmental degradation are being addressed, institutions and capacity are being strengthened, and comparative advantage sectors are rooting, then liberalization, privatization, and stabilization measures (similar to current SAP reforms) can be accelerated. Adjustment loans should explicitly provide for training and technology transfer, perhaps substituting some direct financial capital, appropriate to the resource management and sectoral promotion goals of the borrowing nation.

MATRIX ONE: MACROECONOMIC CHANGE AND POTENTIAL ECONOMIC AND ENVIRONMENTAL OUTCOMES

MACROECONOMIC CHANGE	FORMAL SECTOR EFFECTS	INFORMAL SECTOR OUTCOMES	NATURAL SECTOR OUTCOMES
LONG RUN ECONOMIC AND STRUCTURAL CHANGES	Structural adjustment and stabilization (general)	Mixed; depends on recognition of and accounting for informal sector responses	Mixed; depends on adequate internalization of environmental costs and benefits
	Increase in level of production	Depends on displacement of people and resources	General increase in resource use and waste
	Shift in structure of inputs labor, energy, chemicals, land, natural resources, physical capital, etc.	Labor intensity absorbs labor; chemical or pollution intensity may lower informal sector productivity; land/natural resource intensity may displace resources; capital or energy intensity may displace labor, energy intensity may damage crops through acid deposition	Labor intensity may reduce formal and informal pressure on resources; energy and chemical intensity will degrade resources; land/natural resource intensity may promote better management or more rapid resource depletion; capital intensity in primary sector may cause more rapid degradation,
(Overall package of structural adjustment reforms)	Shift in structure of outputs (agricultural, industrial, service, etc.)	[See relevant SECTORAL POLICY.]	[See relevant SECTORAL POLICY.]
	Change in level of consumption	Decreased formal consumption may induce use of informal substitutes; increased consumption may displace informal activities	Consumption generally entails more resource use and environmental impacts
	Shift in structure of consumption (energy, natural resources, durable, non-durable, etc.)	Depends on informal substitutes	Increased energy demands will pollute; resource demands will deplete; durable (especially non-biodegradable) goods will increase waste stream; service demands will have mixed effects
	Increased economic efficiency	Depends on efficiency gains in informal sector	Conservation of scarce resources; less waste
	Increased technical efficiency	Diffusion of technology to informal sector will increase productivity	Less pollution intensity; better resource management
	Change in level of poverty	Less poverty promotes a healthier and perhaps smaller informal sector; converse also true	Less poverty implies less sacrifice of resource integrity for short-term needs and less encroachment on lands
	Change in income distribution	Increased inequality swells the informal sector	Inequality fuels migration, squatting, short time horizons and resource degradation by poor

MATRIX ONE: MACROECONOMIC CHANGE AND POTENTIAL ECONOMIC AND ENVIRONMENTAL OUTCOMES (continued, 2)

	Change in discount rate (a decrease implying more investment toward *long-term returns*); *lower market* discount rates reduce the difference between private and social discount rates	A lower discount rate may decrease fertility and induce long-term resource management, if felt by the informal sector; lower discount rates may translate into lower informal credit interest rates, hence increasing informal sector investment	Discount rates less than regeneration rates of renewable resources will promote sustainability; may also prolong availability of non-renewables; (low discount rates may also accelerate general development, reducing the above benefits by stimulating capital intensive extractive activities)
PUBLIC EXPENDITURE			
Short-run across-the-board reduction	Demand reduction; increased poverty and unemployment (e.g., due to reduction of public sector employment, public services, subsidies, etc.)	Influx of labor, increased consumption demands for non-marketed goods (e.g., fuelwood)	Decreased pressure on commercial resources, increased pressure on open-access or unpriced resources; reduced pollution abatement in urban sector
Long-run across-the-board reduction	Increased savings and private investment, potential for increased employment	Labor absorption into formal sector -- if formal sector investment is in labor-intensive activity	Depends on nature of activities promoted through investment
Reduction in "low priority" areas (health, education, social and environmental programs)	Demand reduction, lower investment in human and natural capital, and in environmental protection	Less diffusion of information, expertise and technology to help poor manage resources, health, and family planning.	Decline in sustainable resource management, continued population pressure on resources, reduced pollution abatement
Reduction in infrastructure investment other than social or environmental (e.g., roads, dams, etc.)	Reduced public sector employment, slower growth of formal sector (e.g., transport, power, irrigation agriculture)	Reduced displacement of indigenous and low income populations; reduced encroachment and colonization in natural areas	Reduced environmental impacts of large infrastructural projects; reduced destruction of natural areas from encroachment, colonization, commercial development, and other resource exploitation
MONETARY POLICY			
General reduction in credit availability	Generally lower private investment	Influx of labor into informal sector	Increased forest encroachment and other open-access resource exploitation
Specific reduction in soft credit programs	Marked decrease in investment for rural smallholders and small enterprise	Increased informal sector interest rates and reduced investment	Increased forest encroachment and other open-access resource exploitation
Interest rate ceiling removal	Increased smallholder and small enterprise investment	Increased institutional credit availability to informal sector	Reduced farmland mining; increased soil conservation; reduced encroachment

MATRIX ONE: MACROECONOMIC CHANGE AND POTENTIAL ECONOMIC AND ENVIRONMENTAL OUTCOMES (continued, 3)

TRADE POLICY			
Currency devaluation	Reduced balance of payments deficit, increased exports and activity in export sector; higher import costs; sectoral shifts depend on relative prices of factors and goods	Increased demand for labor in export activities may pull women out of household production activities; import price increases may hurt poor by increasing prices of domestic substitutes; increased exports and prices of staple foods benefits rural poor with staples surplus and hurts those with deficits or the urban poor SIMILAR TO SECTORAL POLICY EFFECTS [See below.]	Higher cost of imported technology, capital, and pollution control may decrease abatement and production efficiency gains; increased exports of natural resources; ambiguous impacts on forest encroachment SIMILAR TO SECTORAL POLICY EFFECTS [See below.]
Trade barrier reduction (tariff and non-tariff)	Increased imports; resource shift from import substitution to export-oriented industries	Potential reduced prices for import substitutes may help poor, unless there is a loss of scale economies	Improved efficiency of resource use; reduced costs of imported technology (both resource-saving and resource-using)
SECTORAL POLICY	Changes in sectoral practices and shift of resources among sectors		
Agricultural export promotion	Expanded production of export crops (cash crops); reduced production of staple crops; shift in structure of factor demand and in farming practices; potential displacement of forestry and other primary enterprises	Agricultural export cultivation may impinge on subsistence cultivation while simultaneously reducing supply of commercial foodcrops; potential labor demands may absorb excess labor but also may absorb valuable non-market labor (e.g., female household production)	Extensification of commercial agriculture and relocation of informal agriculture may degrade marginal areas; intensification can have positive (more labor, better management) or negative (soil erosion, chemical or nutrient runoff) effects. Dependent on land base, crops promoted, property rights and degree of internalization of offsite effects (e.g., sedimentation of dams due to erosion)
Industrial export promotion	Industrial expansion; change in sectoral shares of small- and large-scale manufacturing; shift in structure of factor demand and output	Labor absorption depends on whether promoted industry is labor or capital intensive; also depends on location of industry (i.e., rural or urban)	Effects ambiguous but generally positive when promoted industry is labor intensive, negative if capital and energy intensive

MATRIX ONE: MACROECONOMIC CHANGE AND POTENTIAL ECONOMIC AND ENVIRONMENTAL OUTCOMES (continued, 4)

Services promotion (e.g., tourism)	Shift in structure of factor demand and output; generally favorable structural change	Usually favorable employment and income effects;	Ecotourism has generally positive effects; mass tourism generally negative (haphazard tourist development, beach pollution, damage to forests and coral reefs, increased congestion) unless regulated
SPECIFIC PRICE CHANGES (examples)	Reduced use of higher priced goods and inputs; production and consumption effects from relative price changes	Price increases for basic goods may exacerbate poverty; substitutes may entail degradation of open-access or unpriced resources	Ambiguous effects since price increases lead to conservation when property rights are secure and to depletion when they are not and economy is open to trade; likely increase in exploitation of open access resources
Reduction of subsidies on all commercial energy	Incentive for energy efficiency; potential decline in commercial energy use	Decreased reliance on commercial energy, more reliance on non-commercial substitutes	Energy conservation; reduced pollution (local, regional and global); increased fuelwood gathering and charcoal production (causing deforestation and mangrove destruction)
Reduction of energy subsidies on some commercial energy (e.g., oil)	Some incentive for energy efficiency, but also shift toward substitute sources (e.g., coal)	Shift in household energy use toward traditional fuels	Depends on relative pollution by sources (reduced pollutiodn when relative prices favor low-sulfur, low-carbon fuels like natural gas, or renewable energy); may increase deforestation for fuelwood
Reduction of agricultural subsidies	More efficient farm practices; shift toward other sectors or inputs; reduction of pesticide, fertilizer and irrigation subsidies have short-term negative economic effects on the sector but usually have favorable long-term economic benefits	Informal sector benefits indirectly by the removal of agricultural subsidies that favor the formal sector	Reduced cultivation of fragile and marginal lands; reduced non-point-source water pollution; reduced water-logging and salinization of soils from overirrigation,; reduced damage to natural predators of pests and to biodiversity and wildlife; more sustainable agriculture
Reduction of industrial subsidies	More efficient industrial practices; shift toward other sectors or inputs	Favors artisanal sectors; increased industrial employment (since subsidized industrial sectors such as iron and steel, cement and petrochemicals are capital intensive) reduces surplus labor and raises returns in the informal sector	Reduced encroachment on open-access resources and squatting in public property and slums; reduced solid waste dumping in public places

MATRIX ONE: MACROECONOMIC CHANGE AND POTENTIAL ECONOMIC AND ENVIRONMENTAL OUTCOMES

(continued, 5)

Increased stumpage fees and timber taxes (and other forms of resource rent capture)	Decreased rates of commercial timber extraction; shift toward less heavily taxed land use activities (unless non-timber values of forests are internalized)	No direct effect on rates of informal forest conversion or extraction, but more forest resources may become available for harvest of non-timber goods; commercial agricuture may displace subsistence farms	Potential decrease in commercial deforestation, may be offset by extensification of commercial agriculture; displacemed subsistence farmers may increase pressure on marginal lands
Other "green" taxation (internalizing external costs of various goods and services)	Reduced resource waste; increased efficiency; relative price effects will change patterns of consumption and production; government revenue generated	Price changes may induce more exploitation of open-access or unpriced resources	Generally favorable effects on resource sectors and environment (reduced depletion and pollution); government revenues generated may be used for environment
INSTITUTIONAL REFORM	Promotes more predictable, efficient markets	May "formalize" informal markets	Necessary for resource incentives to work
Land tenure security	Increased market value of land; increased access to credit and increased incentives for long-term investments	Consolidation of commercial lands may displace rural poor; but establishment of rights on their lands will promote sustained production and longer time-horizons	Increased soil conservation; tree planting; long-term management of land resources
Land tenure arrangements	Privatization of open access generates efficiency gains	Privatization deprives poor and landless of last resort source of income and employment; communal management is a preferred arrangement	Requirements that land be cleared to establish tenure promote deforestation; requirements for sustainable management are clearly beneficial
Increased regulatory enforcement	Will ensure regulatory compliance but may increase productions costs in short run	No direct impacts; potential for greater regulation of informal activities (with mixed effects on informal sector production and welfare	Reduced urban and industrial pollution; generally more predictable environmental outcomes from policy
Reduced corruption and collusion	Reduced rent-seeking behavior; some short-term costs and long-run benefits	Unclear connection; potential to remove biases against informal sector production and welfare	Reduced use of natural resources as political resources
Formalized communal property arrangements	Loss of claims to open-access resources	Increased control and empowerment; increased efficiency and reduced poverty	Resource conservation and management; correction of tragedy of the commons

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES

COUNTRY & TIME SPAN[1]	AUTHORS (STUDY DATE)	METHODS OF STUDY[2,3]	MACROECONOMIC AND POLICY FACTORS[4]	ENVIRONMENTAL FACTORS[5]	SUMMARY OF SELECTED FINDINGS, RESULTS, AND RECOMMENDATIONS[6]
Cameroon 1985-1994	WWF/ODI (1994)	-Historical -Analytical -Case studies	-Ag. price and marketing reform -Credit availability -Currency devaluation -Public expenditure	-Ag. practices -Forest conversion -Poverty conditions	FINDINGS -Price reform for cash crops (reducing producer price) led to less maintenance (-) and less output (+) from plantations, and relative prices then favored more soil-erosive food crops (-). -Devaluation encouraged extensification of ag. exports (-) and restoration of some plantations (+/-). Some soil-erosive food crops have been disfavored by ag. export growth (+). -Cuts in extension services discouraged intensification, diversification, conservation, and agro-forestry (+), and rural credit reductions also disfavor intensification (+). -Cuts in Forestry Service exacerbate unsustainable logging, and new Forestry Code, the only environmental provision in the SAP, is inadequate to promote sustainability (-). -Fuel price increases encourage use of substitute woodfuel, thus causing deforestation (-). -Decreased social spending, especially for education, health, and women's empowerment, have exacerbated poverty and unsustainable practices (-). RECOMMENDATIONS -Resource planning and legislation should be expanded and reformed, including forest and wildlife legislation, comprehensive env. laws, and a nationwide land use plan. -Institutional reform and strengthening are prerequisites. -Rural credit should be expanded and guaranteed. -Adjustment programs should protect env. funding and the poor. -Reforms need to be sequenced, balanced and gradual to avoid excessive shocks, internal contradictions, and disproportionate hardship.

1 Most studies have provided a historical overview of development experience. The TIME SPAN element refers to the period during which structural adjustment programs were being implemented. If a specific period is not given in the study, the appropriate decades are listed (e.g., 1980s, or 70s-80s)

2 *Any number of methods may have been utilized for the individual studies.* **Only selected methods**, that granted the most insight into adjustment-environment linkages, are given here (most often as Historical, Analytical, Case Studies, or various quantitative models). Virtually all studies have relied upon secondary research, so it is not mentioned unless that was the specific intent of the study (e.g., Meta-analysis). "Analytical" implies that some quantitative data analysis appears to have been utilized, and "Historical" implies a primarily narrative coverage of events.

3 The common abbreviations here are: -PE (partial equilibrium), CGE (computable general equilibrium), LP (linear programming), and SAM (social accounting matrix).

4 *There is great variability among the studies in the taxonomy of adjustment*, and this is reflected in the notation of "factors" in this column. Where specific reforms such as devaluation or ag. subsidy cuts are tied to a specific environmental outcome, those specific reforms are noted. Where, as is more generally the case, categories of reform are covered, the notation is more general (e.g., trade liberalization, price reform). Some taxonomic consistency is sacrificed in the name of contextually accurate representation.

5 As with macroeconomic and policy factors, environmental factors may be specific or general, depending on the perspective of each study.

6 These categories are listed separately within the column. The notes are drawn selectively from the studies according to their relevance to structural adjustment and the environment, and are **not intended to be a comprehensive summary of the studies**. FINDINGS include documented trends and observations from analysis. RESULTS refers to relevant insights from any quantitative models that may have been used. RECOMMENDATIONS include relevant policy recommendations and, where explicitly noted, recommended areas for further research. Where it may not be obvious, enerally negative environmental impacts are noted by (-), positive effects by (+), and mixed effects by (+/-).

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 2)

Chile 1983-1992	International NGO Forum (1992)	-Historical (cursory)	-Trade liberalization	-Deforestation -Ag. practices -Fisheries	FINDINGS -Promotion of non-traditional exports, specifically certain wood products, has caused deforestation. -Timber exports promoted deforestation. Replanting of non-native trees has caused soil erosion, and pesticide/agrochemical problems. -Export fishmeal industry has displaced subsistence fishing and led to overharvesting and species decline. (Toxic effluent also responsible.) -Fruit exports have encouraged damaging chemical intensification.
China (??)	Tao & Warford (*in* Munasinghe & Cruz, 1994)	-Survey data -*Partial* equilibrium models	-Reducing ag. subsidies -Increased opp. cost of ag. labor from industrial growth -Lifting ag. import quotas	-Ag. practices -Pesticide use -Fertilizer use -Energy use	RESULTS -Lifting ag. input subsidies generally decreases overuse of pesticide & fertilizer, but relative price changes make the relationship uncertain. -Increasing prices for commercial energy reduce use, but biomass energy will increase, entailing higher demand for chemical fertilizer and effects from biomass burning. RECOMMENDATIONS -Policy reform must accompany market reform to get predictable and environmentally beneficial results. -Intervention will be necessary to correct market failure.
Costa Rica 1982-1991	Cruz et al. (1992)	-Historical -Analytical	-General adjustment policies	-Deforestation -	FINDINGS -Reforms increased poverty and unemployment, exacerbating frontier migration, forest conversion, and land degradation. -Failure to account for informal sector response, population trends, and common property resources exacerbated env. degradation.
Costa Rica 1980-1993	Hansen-Kuhn (1993)	-Historical -Analytical	-General adjustment policies	-General -Poverty	FINDINGS -Focus on ag. exports, particularly non-traditionals, has promoted deforestation, chemical intensity, instability, and health problems. -Reforms have exacerbated income disparity, with negative env. implications from migration, poverty, and decreased public investment. -Major institutional factors (e.g., land tenure) have not been addressed.
Costa Rica 1985-1992	International NGO Forum (1992)	-Historical (cursory)	-Trade liberalization -Export promotion	-Agrochemicals -Deforestation -Human health	FINDINGS -Chemical intensification in booming ag. exports caused severe env. degradation and health problems. -Increased poverty from a regressive tax structure, and chemically degraded land, have prompted conversion of marginal uplands. -Concentration of land among wealthy and foreign investors has generally exacerbated above trends.
Costa Rica (??)	Persson & Munasinghe (in Munasinghe& Cruz, 1994)	-CGE model (includes property rights simulation)	-Property rights -Discount rate (or interest rate) -Increased wage rate	-Deforestation -Soil erosion	RESULTS -Higher interest rates encourage deforestation, while lower ones increase conservation. -Increased stumpage prices, while reducing logging, promote deforestation indirectly through increasing ag. forest conversion. -Similarly, increased wages for unskilled labor reduce logging (formal sector) but they shift resources to informal agriculture and forest conversion.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 3)

Côte d'Ivoire	CIRES (in Reed, 1992)	-Optimal control model (forest sector only) -Econometric analysis -Historical -Analytical	-Public expenditure reduction -Currency devaluation (hypothetical) -Tenure and institutional reform -Trade liberalization -Sectoral policies	-Land tenure -Deforestation -Soil degradation -Pollution	FINDINGS -Land degradation is primarily due to insecure land tenure. -Pollution probems result from poor regulation, perverse subsidies, and failure to account for negative env. externalities. -Devaluation, now impossible, would decrease domestic demand. -Lack of urban labor absorption may exacerbate rural degradation in the informal sector in the presence of demand reduction. RESULTS -Optimal forest stock is far greater than actual forest stock, using either previous yield coefficient estimates or econometrically revised ones. -Tenure insecurity and institutional failures, represented by a high discount rate, accelerate forest conversion and degradation. -Increases in ag. output prices, relative to forest products, increase deforestation, but decreased domestic demand may decrease conversion. -If externalities were included in the analysis, both env. damages and benefits from sustainable policies and practices would be greater.
El Salvador 1985-1993	WWF/HIID (1994)	-?? -Historical -Analytical	-Public expenditure -Exchange rate devaluation -Pricing reform -Tax reform	-Surface & ground water pollution -Land use -Deforestation	FINDINGS -Industrial bias of reforms increased rural poverty, unsustainable ag. practices, and fuewood-gathering. (Civil war exacerbated this.) -A lack of regulation to accompany economic growth has caused severe deterioration of the urban environment -Despite greater domestic & multilateral attention to env. needs since war ended, institutional weakness impedes env. improvements.
Ghana 1984-1992	International NGO Forum (1992)	Historical (cursory)	-General stabilization -Timber export promotion	-Deforestation -Poverty	FINDINGS -Devaluation, wage cuts, and reduced public expenditure mainly hit the poor and led to greater pressure on marginal lands. -Unsustainable logging has increased from timber export promotion, causing desertification, land productivity losses, and other env. problems.
Ghana	Lopez (in Munasinghe & Cruz (1994)	-PE model	-Trade liberalization -Reduced public expenditure	-Ag. productivity -Land use	RESULTS -Higher prices or lower input cost for ag. products tends to increase cultivated area far more than ag. intensity. Family size, capital availability and migrant population also increase cultivated area. -Price and wage reform will not significantly increase national income unless it includes reform of land management, especially the tenure system (currently similar to shifting cultivation.) -Public expenditure reduction, including reduced public employment, could increase ag. productivity and national income.
India 1991-1993	Kothari & Kothari (1993)	-Historical	-Trade liberalization -Privatization	-General	FINDINGS -Increased export values theoretically promote sustainable production of the export goods, but experience has shown that environmental and social responsibility are sacrificed for short-run profits. -Privatization of state enterprises may encourage even worse management of natural resources; public institutional reform is preferable. -Alternative growth strategies exist, focusing on democratization, common property management, human development, and env. sustainability.
Indonesia 1979-1989 (proj. to 2020)	Wheeler & Martin (in Munasinghe & Cruz, 1994)	-PE model -Historical -Econometric projections	-Trade liberalization	-Industrial pollution intensity, location, and absolute level	RESULTS -Environmental regulation must accompany macro reforms to mitigate environmental side-effects of industrial growth. -Promotion of assembly processes, cleaner than materials processing, has led to lower pollution intensity, but overall levels are rising dramatically. A poverty-pollution tradeoff is evident.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 4)

Jamaica	WWF/HIID (1994)	-?? -Historical -Analytical	-Public expenditure -Trade & pricing reform -Sectoral biases	-Water pollution -Air pollution -Land use -Deforestation	FINDINGS -Fiscal tightening has threatened an already weak env. control apparatus. -Reforms have reduced env. harmful subsidies and trade barriers. -Export sectors (bauxite, coffee, manuf., & tourism) were boosted without appropriate environmental considerations or controls resulting in large-scale land degradation, air pollution, water pollution, and unsustainability. -Kerosene, other fuel, & fuelwood pricing policy is not well coordinated. -Stumpage fees are still far below replacement cost, inducing deforestation and an implicit subsidy to coffee growers. -Inequity, weak institutions, and market failures threaten economic growth and will deter env. improvement until they are addressed.
Malawi	Cromwell & Winpenny (1993)	-Conceptual model -Historical	-Price reform -Trade liberalization -Currency devaluation -Privatization of ag. markets	-Ag practices (i.e., -Spatial extent -Product mix -Prod'n intensity -Prod'n technique)	FINDINGS -Reforms' effects on environment vary according to types of crops cultivated, extensity, intensity, and technique. -Reforms affect smallholders and estate-holders differently. -Overall, reforms have limited the extent of cultivation, sparing fragile lands at the margin, and other effects are specific and varied. RECOMMENDATIONS -Without population stabilization and more off-farm employment opportunities, rural env. degradation will continue. -More ag. extension and access to capital and technology are needed.
Mali 1980-1994	WWF/ODI (1994)	- ?? -Case studies -Analytical -Historical	-Currency devaluation -Liberalization and privatization of agricultural markets	-Ag. practices	FINDINGS -Devaluation intensified and extensified cotton production and brought temporary pasture relief through livestock exports. -Ag. liberalization & price reform has mixed effects -Privatization increased farmer responsibilty. -??
Madagascar 1989-1994	Barrett (1994)	-Historical	-Currency devaluation -General liberalization	-Env. NGOs -Ag. practices	FINDINGS -Devaluation hurts international env. NGO operations, which are import-intensive, while it contradicts NGO objectives by increasing ag. extent and extraction of forest products. -Foreign exchange inflows for environment have been far greater than IMF/World Bank inflows, allowing govt. to "play" interests off one another and balance stabilization and env. objectives.
Mexico 1980-1986	Adelman & Taylor (1990)	-SAM	-Agricultural policy -Wage repression	(INDIRECT) -Farm scale -Poverty	RESULTS -Agriculture-led development which removes biases against small farmers leads to higher growth and welfare than industrial-led growth. -Increasing minimum wages would have accelerated, not deterred, growth. -Rural productivity-enhancing policy, rather than urban income-enhancing policy, provides higher growth rates for industry and agriculture, and alleviates rural poverty.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 5)

Mexico 1989-1992	ITAM (in Reed, 1992)	-Analytical -Historical	-Reducing public expenditure -Tax & domestic price policy -Maquiladora program -Energy pricing -Privatization	-Soil erosion -Deforestation -Water resources -Poverty -General	FINDINGS -Public expenditure reductions have hit env. programs harder. -Oil, rather than forest, resources have been overexploited in order to finance debt repayment and ensure economic stabilization. -Inappropriate subsidies and overvaluation still promote soil-erosive annual crop production and chemical-intensive agriculture. -Border manufacturing (maquiladoras) suffers insufficient env. regulation. -Increased energy prices and demand reduction stem energy pollution but hurt environment through increased unemployment, poverty and migration. -Privatization effects are unclear but induce efficient resource allocation. RECOMMENDATIONS -Env. resources should be priced to reflect externalities, but perhaps rationed for vulnerable groups. -Land tenure issues need to be addressed to stem forest conversion. -International cooperation (e.g., debt-for-nature, funding) should be provided to mitigate excessive deforestation. -Better data collection, institutions and policy will be necessary to treat forest, water resource, and other env. issues.
Mexico 1950-1990	Eskeland & Ten-Kate (in Munasinghe & Cruz, 1994)	-PE model -Historical	-Trade liberalization -Industrial policy -Taxation	-Industrial pollution -Urban air pollution	RESULTS -Trade liberalization supported low-pollution, consumer good industries. -Structural change, including public investment in petro- and agrochemical industries increased air, water, and toxics pollution. -Fuel taxes would reduce urban vehicular pollution and internalize environmental costs. Emissions taxes are appropriate for point sources. -Some regulation (clean fuel or energy efficiency) would complement market reforms to correct for market failure (externalities).
Morocco 70s-80s (proj. to 2020)	Goldin & Host (in Munasinghe & Cruz, 1994)	-CGE model -Econometric projections	-Trade liberalization -Water pricing reform	-Water use	RESULTS -Water price reform alone would decrease urban and rural water use by about a third, but GDP and consumption would fall slightly. -Trade liberalization alone increases GDP and consumption significantly, but water use increases as well. -With both reforms, real GDP growth occurs while water use falls.
Pakistan	WWF/HIID (1994)	-Econometric growth model	-General reform (proxy variable = savings rate)	-Water quality -Sanitation -Waste generation (INDIRECT)	RESULTS -Reform (relative to no reform) reduces water quality and sanitation problems; the peak of the "environmental Kuznet's curve" comes sooner. -Reform with population stabilization further reduces env. degradation. -Reform nonetheless increases urbanization and waste generation.
		-CGE (& SAM)	-Trade liberalization -Tax increases -Energy price increase -Deficit reduction -Exchange rate devaluation	-Agric. sector -Manuf. sector	RESULTS -Reforms generally increase the marginal return to labor, which may or may not translate to higher wages. -Reforms induce a higher ag. share of labor, implying de-urbanization, but total urban pop. will still increase and exacerbate urban env. problems. -Trade liberalization would favor small-scale manufacturing (with lower pollution intensity than large-scale), but regulation of same is difficult. -Reforms increase govt. revenue, which might help env. programs.
		-LP model	-Ag. input prices -Ag. output prices	-Ag. practices -Waterlogging -Salinity	RESULTS-Increasing input and output prices tends to increase cropped area in "fresh" areas, but not in already saline areas. Some land reclamation may occur. -Aggregate fertilizer use will increase due to extensification. -Waterlogging may be ameliorated through price-induced changes in irrigation practices.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 6)

Phillipines 1983-1991	Cruz et al. (1992)	-Historical -Analytical	-General adjustment policies	-Land use -Poverty	FINDINGS -Reforms induced poverty and frontier migration, exacerbating forest conversion and land degradation. -Failure to account for population, migration, open access resources, and informal sector responses contributed to unsustainable development.
Phillipines 1979-1992	Cruz & Repetto (1992)	-CGE model -Historical -Analytical	-General stabilization -General adjustment policies MODEL -Tariff reduction -Currency devaluation -Energy tax -Industrial subsidy -Resource rent tax	-Land use -Fisheries -Energy -Poverty -Other general MODEL -Soil-erosive ag. -Primary sectors -Energy sector -Factor prices -Income distribution	FINDINGS -Pre-SAP policies encouraged resource extraction, disinvestment in primary sector, energy- and material-intensity, taxed regressively, and failed to manage common property resources. Major resource depreciation occurred in forestry, soils, and coastal fisheries. -Poverty, population, and property rights have been major culprits in resource degradation. Stabilization policies may have exacerbated this. -Adjustment policies had inadequate env. and institutional components. RESULTS -Trade reform (tariff reduction and devaluation) increased soil erosion, deforestation, fishery exploitation, energy use, migration pressure, and demand for land, but improved incomes and income distribution. -Energy taxation decreases env. degradation, improves income distribution and BOP, but constrains economic growth. -Industrial subsidization promotes env. degrading sectors. -Resource rent taxation substantially reduces resource exploitation, reduces pressures on land, improves income distribution and BOP, and erosion-prone agriculture and aggregate output decline marginally. RECOMMENDATIONS -SAPs need to integrate informal sector responses (e.g., migration, ag. practices) and broad env. concerns more fully. -Resource rent taxes and env. charges, integrated with traditional adjustment measures, are required for sustainable development. -Trade liberalization's env. effects must be weighed against export gains. -Perverse industrial incentives in SAPs should be dropped. -Biases against sustainable ag. practices should be eliminated. -Accounting methods should include env. resources; more methodological research and env. data collection are required in this area.
Phillipines	Cruz & Francisco (in Munasinghe & Cruz, 1994)	-PE model -Historical	-Government management -Pricing policies -General	-Deforestation -Ag. practices	RESULTS -Industry-led growth strategy (pre-SAP) penalized lowland agriculture, while growth strategy failed from mismanagement. Ensuing poverty and poor labor absorption resulted in upland migration and forest conversion. -Forestry programs, tenure and market reform are lacking.
Phillipines 1980s	International NGO Forum (1992)	Historical (cursory)	-General -Trade liberalization	-General	FINDINGS -Ag. price reforms have de-intensified commercial agriculture. -Tight monetary policy and lack of rural credit has forced smallholders off land, worsening rural poverty and degradation of common resources. -Oil subsidy cuts have decreased env. degradation in formal sector, but may have negative effects in informal sector.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 7)

Poland 1970-1991 (proj. to 2010)	Bates, Gupta & Fiedor (1994)	-LP model (dynamic optimization) -Analytical -Historical	-Pricing policy -Institutional change	-Energy use -Air pollution	RESULTS -Energy pricing reform results in lower energy intensity across all productive sectors, but industrial growth will entail higher aggregate consumption. -Per capita energy consumption will likely increase with rising incomes. -Pollution intensities will fall with reforms, and aggregate levels of sulfur dioxide, nitrogen oxides, and particulate matter (the biggest health threat) are projected to fall. Carbon dioxide emissions will increase. RECOMMENDATIONS -Institutional reform is required for env. policies to be effective.
Poland 1980-1982	Zylicz (in Kierzkowski et al., 1993)	-Historical -Analytical	(from market transition) -Recession -Trade liberalization -Taxation	-Air pollution -Water pollution -Hazardous waste	FINDINGS -Initial decrease in industrial production from recession caused a temporary decrease in air and water pollutant emissions from industry. -World Bank projections showed that air pollution will increase due to increased industrial production from structural adjustment. -Liberalized trade, without appropriate environmental regulation, allowed excessive "imports" of hazardous waste. -PPP would presently shut down too many industrial plants and must wait. RECOMMENDATIONS -Reforms must be accompanied by policies such as decentralization, stronger property rights, emissions markets, pollution control subsidies, and, only when industry becomes competitive enough, Pigouvian taxes.
Sri Lanka (proj. to 2010)	Meier et al. (in Munasinghe & Cruz, 1994)	-PE model	-Energy pricing -Energy policy	-Greenhouse gas (GHG) emissions	RESULTS -DSM (demand-side management) would be a difficult and non-comprehensive strategy for reducing GHGs, whereas pricing reforms would be easier and have better net impact for the environment. -Carbon taxes will be effective as energy demands increase over time.
Tanzania 1980-1990 (proj. to 2010)	WWF/ODI (1994)	-Conceptual model ?? -Econometric projections -Survey data	-Pricing policy -Tax policy -Trade liberalization -Institutional reform	-Deforestation -Soil erosion -Other general	FINDINGS -Reforms have promoted extending ag. margin, while increased input prices and limited technology access have discouraged intensification. -Poor ag. extension and land law have not been addressed. -Inappopriate incentives still promote deforestation and soil erosion. RESULTS -Present SAP policies will increase income and power inequality, while inducing env. degradation in the informal sector. -Lack of internalized env. costs will lead to overexploitation of resources, with only short-run gains for the elite. -Alternative sustainable SAPs (including subsidized ag. inputs, tariffs on polluting inputs/industries, public expenditure stability, ??) would slow increases in air pollution, energy and water use, while reducing deforestation, biodiversity loss, and soil erosion. RECOMMENDATIONS -Objectives of SAPs should include participatory development, govt. accountability, assistance for vulnerable groups, and integration of env. and social factors. -Pacing and sequencing reforms with priority to social sector restructuring and institutional strengthening is advised. -Parallel policy priorities include ag. extension, land tenure reform, logging/industrial taxation and regulation, wildlife protection, energy efficiency R&D, and improved credit for small farms and enterprises.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 8)

Thailand	Panayotou & Sussangkarn (1991)	-CGE Model (90 sector) -Analytical -Historical	-General market -General institutions -General policies MODEL -Reducing export taxes -Increasing oil prices -Promoting labor-intensive manufactured exports -Promoting tourism -Reducing public expenditure	-Land use -Pollution -Poverty -Population	FINDINGS -Industrial export-led growth has sacrificed env. integrity. -Adjustment policies have failed to account for env. externalities. -Population and poverty issues are equally crucial development variables. -Institutional (e.g., land tenure, enforcement), market, and policy failures account for most unsustainable development practices. RESULTS -Cuts in rice and rubber export taxes stimulated agriculture at the expense of industry and service, reducing pollution and tourism-related degradation, but with mixed env. effects for agriculture. Rice is chemically intensified (-), but entails more investment and improvement. Rubber is extensified onto some marginal areas (-), but replaces some more erosive crops in already cultivated lands (+). -Oil price increases generally reduce energy intensity and use across most sectors, thus reducing pollutant emissions. -Increased labor-intensive exports entail generally less aggregate pollution and degradation, but often contribute to toxic and water pollution. -Tourism effects include ag. reduction (+), transport increases (-), and accelerated coastal and mangrove destruction (-). More research needed. -Public expenditure reduction reduces urban and industrial pollution, but increases resource depletion, deforestation, and ag. pollution.
Tunisia	Mink & Partow (in Munasinghe & Cruz, 1994)	-PE model ?? -Historical -Analytical	-Pricing policies (in livestock sector)	-Rangelands -Desertification -Soil erosion	RESULTS-Pricing reforms will have differential effects on livestock production across regions, though they are likely to balance livestock with agriculture. -Higher beef prices will likely increase the herd size, causing further pressure on already marginal lands. RECOMMENDATIONS -Structural adjustment policies have not adequately accounted for the environmental externalities of the large livestock sector.
Venezuela 1989-1993 (proj. to 2003)	WWF/HIID (1994)	-Macro model (CGE ??) -Historical -Analytical	-?? (not well specified) -Trade liberalization -Currency devaluation -Pricing policies	- ?? -Urban environment -Land use -Pollution -Parks	FINDINGS -Despite compensatory social programs, adjustment policies have worsened social conditions and degraded the urban environment; rural env. effects are unclear. -Poor coordination and enforcement of public agencies have negative env. effects, particularly with regard to the oil industry. -Reforms gave lower priority to env. objectives. -Env. legislation and enforcement need strengthening and reform. -NGO/collective action has been undermined by adjustment process. -Env. expenditure cuts and privatization have had mixed env. effects. -Park system cuts, mining pressure, and informal ag. encroachment/exploitation may be threatening protected areas. RESULTS -A pure free market reform scenario displays far worse env. outcomes than exchange control or exchange control and redistribution. -Institutional and env. policy reform might change above result. -Sociopolitical feasibility analysis reveals that env. conservation would respond positively to increased oil revenue, negatively to foreign capital inflows, and insignificantly to social peace, alternative technology, institutional stability, or "ipressure from the IMF."

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 9)

Vietnam 1986-1993	WWF/HIID (1994)	-CGE model -Historical -Analytical	-Trade liberalization -Pricing policy -Property rights -Direct foreign investment -Development assistance	-(De/re)forestation -Land use -Waste -Water & air pollution	RESULTS -Labor- and technology-intensive, rather than energy-intensive, industry would reduce waste, air & water pollution problems. -Continued macro stability and reform will promote sound resource management, especially when combined with appropriate price policy. RECOMMENDATIONS -Ag. policy & investment must balance that of industrial promotion. -Property rights reform, internalization of env. costs, and regulation are all necessary preconditions for sustainable growth with reforms. -Market-based env. policy should be pursued, but with enforcement and, where necessary, regulation to prevent irreversible env. effects.
Zambia 1985-1993 (proj. to 2010)	WWF/ODI (1994)	-CGE model -Econometric projections -Analytical -Historical	-Pricing Policy -Public management -Regulation -Trade liberalization	-Deforestation -Biodiversity -Water pollution	RESULTS -Adjustment policies should lead to less investment in commercial agriculture, but more shifting cultivation and rural migration. -Poverty and inequity have been exacerbated by adjustment, but it is "hoped" that future reforms will treat those issues. -Woodfuel gathering will exacerbate deforestation unless electric sources are subsidized. -Wildlife/env. programs may reduce poaching and pollution, but funding and institutional viability are key factors. -Demand reduction policies should be pursued only insofar as they are shown to improve social welfare. They are not an end, but a means. -Adjustment policies have failed to account for the lack of preexisting markets and effective institutions, thus contributing to waste and damage.
Zimbabwe 1991-1992	International NGO Forum (1992)	-Historical (cursory)	-Trade liberalization -Currency devaluation -Price reform -Public expenditure	-Ag. practices -Water resources -General	FINDINGS-Fiscal austerity and rising food prices from devaluation exacerbated hunger and poverty during a major drought, triggering further encroachment on marginal lands and mismanagement of water resources. -Lack of land reform favors wealthy, white landowners while worsening environmental conditions and poverty for rural blacks.
Zimbabwe	Muir, Bojö & Cunliffe (1994)	-Analytical -Historical (some basis on BCA's)	-Currency devaluation -Fiscal & monetary policy -Land tax -Pricing policy -Trade controls	-Wildlife management -Land use	FINDINGS -Devaluation corrected market distortions (on imported inputs) and increased access to foreign exchange, boosting wildlife tourism and hunting activitiies -- presumably an incentive toward better resource management. -The lack of fiscal responsibility and low priority afforded to resource management programs continues to adversely affect the environment. RECOMMENDATIONS -A proposed land tax should increase land utilization and may be biased toward intensive agriculture, with probable negative env. impact. -Pricing reform for beef would reduce the herd and its impacts. -Substantial institutional and policy reform are needed.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 10)

REGIONAL STUDIES

Africa 80s-90s	Krugmann (1994)	-Historical	-General adjustment policies -Trade liberalization	-Desertification	RECOMMENDATIONS -Env. data must be collected and policy analyses must be multidisciplinary, integrating env., social, and economic issues. -Pricing policies and general reform should account for env. externalities. -Small-scale, labor-intensive ag. and enterprise should be promoted. -Pastoral economies should be balanced with ag. export promotion. -Harmonization and institutional reform are vitally needed. -Participatory development and apt institutions should be sought. -Internalization, participation, harmonization, and attention to vulnerable groups/sectors are also required for effective trade liberalization. -Regional integration and intra-African trade should be promoted. -Env.-friendly tourism should be a priority sector for some countries. -Community access to information should be facilitated and communications control should be liberalized. NGO/grassroots can be integral.
Sub-Saharan Africa 1980s	Cheru (1992)	-Historical -Analytical	-General adjustment policies	-General	RECOMMENDATIONS -Land reform and rural development strategies, emphasizing diversification and local consumption, should have priority. -Ag. institutions, such as extension, research, marketing and credit, should be developed, strengthened, and reformed -- not cut. -Access of poor to infrastructure, technology, education and services, especially for resource management, must be improved. -Govt. efforts should integrate efforts with NGOs and cooperatives. -Reproductive health and women need greater emphasis in rural areas. -Labor-intensive, diversified, sustainable agriculture needs promotion. -Debt relief should be conditioned on sustainability and democratization. -Local governments should be held accountable for above reforms.
Sub-Saharan Africa	Adams (1992)	-Historical	-General adjustment policies -MDB structure and practices	-General	FINDINGS -World Bank and IMF are not subject to public scrutiny or private market discipline, and have thus made environmentally, socially, and economically irresponsible judgements in adjustment lending. -A vicious circle of lack of accountability for the MDBs and dependency of LDCs promotes liquidation of natural resources, lack of attention to human and natural capital investment, and general unsustainability.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 11)

THEORETICAL OR IMPACT-SPECIFIC STUDIES

(theoretical)	Barrett (1992)	-Optimal control model	-Input/output price changes -Discount rate	-Soil erosion	RESULTS -Input and output price change effects on soil conservation cannot be generalized and are site- and technique-specific. -Contrary to Barbier's (1988) finding that higher discount rates discourage soil conservation, these results are ambiguous. -Generalizations about adjustment reforms and soil conservation often ignore farmer incentives for conservation or depletion. -Soil erosion is not necessarily suboptimal, but externalities need to be borne by soil depleters to achieve optimality.
(theoretical)	Girma (1992)	-Dynamic macro & micro model (??) -Benefit-cost analysis	-Monetary policy -Fiscal policy -Market reforms -Institutional reforms	-General	RECOMMENDATIONS -Env. sector can and should be integrated with other sectors in macroeconomic models. -Market failure should be accounted for to avoid policy failures. -Research should be undertaken to inject env. factors into CGEs. -Institutional reform is necessary for env. market efficiency, and env. market intervention should be only a second-best resort. -Env. CBAs should accompany env. impact assessments.
(various LDCs)	Martens (1989)	-Legal -Analytical	-General	-Deforestation	RECOMMENDATIONS -Environmental SALs should be formulated, specifically focusing on, rather than marginalizing, resource concerns. -Key features of said programs would be participatory planning, Bank flexibility, NGO participation, and strict enforcement procedures.
(African LDCs)	Due & Gladwin (1991)	-Analytical -Discussion	-General	-Gender and environment	FINDINGS -Since gender division of labor rules force women in African LDCs produce mostly nontradable goods, SAPs are biased against female welfare, production and productivity.
(various LDCs)	Mehra (1991)	-Analytical -Discussion	-General	-Gender and environment	FINDINGS -SAPs have restricted their own success by ignoring structural constraints and production demands on women farmers. More attention to female nonmarket productivity can yield high returns.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 12)

OVERVIEWS AND META-ANALYSES (in chronological order)[7]

(various LDCs)	Hansen (1988)	-Historical -Discussion	-General	-General	FINDINGS -Traditional treatment of environmental issues in lending, in a project-by-project framework, is inadequate; integration of environment in macro policy will be more manageable and effective. -Neither structural nor sectoral adjustment loans have sufficiently targeted environmental objectives. -The environmental ramifications of adjustment's effects on poverty, agricultural practices, migration, infrastructure, and fiscal austerity may be reasonably approximated and integrated into policy planning. -Further research, data collection, and information disemination are paramount in this area. -Political feasibility and committment are prerequisites for effective policy implementation. -Global commons issues and external terms of trade must also be considered and addressed.
(various LDCS)	Sebastian & Alicbusan (1989)	-PE models (for 43 countries) -Historical -Meta-analysis	-General	-General	RESULTS -In aggregate, SAPs may have a net positive impact on the environment through correcting market failure, enabling market mechanisms, and reforming institutions. -Price adjustments (e.g., changes in subsidies, taxation) in agriculture and energy have had positive environmental effects where resources have shifted toward less-degrading activities. -Programs, policies, and trade arrangements which have introduced, promoted, or opened channels for new technology and techniques in agriculture or energy conversion imply efficiency and sustainability gains. -Devaluation can inhibit new technology and capital imports (-) and may require complementary trade or pricing policies to promote environmentally sustainable technology transfer or investment. -Public expenditure reductions may reduce aggregate demand (+), cut environment and agriculture programs (-), or exacerbate conditions of poverty (-). -Institutional reforms in marketing, land use, land tenure, and conservation will have positive effects. RECOMMENDATIONS -Current policy measures can be "modulated" to meet environmental objectives. -Environmental policy formulation must consider institutional changes, input price composition and responses, responses to incentives (elasticity estimates), fostering environmentally benign technology use, and effectively channeling information and market signals. -Analytical frameworks should include the interactions of political, technological, and macroeconomic factors with all productive assets -- including the environment -- in an economy.

7 Publications in which the main body of analysis involves country studies have been broken down by country and included in the "Country Studies" section.

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 13)

(various LDCs)	Hansen (in Winpenny, 1991)	-Discussion -Meta-analysis (of 93 World Bank and ADB structural adjustment programs)	-General	-General	FINDINGS -Across-the-board public expenditure cuts may have positive environmental effects through reducing harmful infrastructure projects and subsidies, but may exacerbate poverty and resource destruction in the informal sector. -Cuts in environmental programs will probably be harmful. -Increases in ag. output from liberalization may conserve soil (if tree crops are grown) or deplete it (if cash & food crops are grown). -Increased ag. output prices should encourage better stewardship, but may increase cultivation intensity and extent. -Increased ag. input prices may induce land conservation. -Increased energy prices may reduce pollution & use, but may induce exploitation of open access resources or harmful energy substitutes. -More data are needed on interactions between formal & informal sectors.
(various LDCs)	Killick (in Winpenny, 1991)	-Discussion	-General	-General	FINDINGS (PROS) -Macro stability reduces economic uncertainty, promoting more predictable policy responses and better resource management. -Good macro management should achieve higher living standards, decreasing the tendency to mortgage the future to serve basic needs. -Stability promotes "pro-future," rather than short-term "crisis-driven" policy. FINDINGS (CONS) -Structural shifts from non-tradeable to tradeable tend to increase pollution, non-renewable resource use, and ag. intensity. --Short-term macroeconomic targets put env. objectives at a lower priority. --Privatization/deregulation weakens potential for mitigating externalities. -Shifts in power structure and philosophy favor capitalists & industrialists, making regulation and taxation of same more difficult politically.
(various LDCs)	Reed (1992)	-Meta-analysis -Case studies (3 countries) -Discussion	-General	-General	RECOMMENDATIONS - - - - - -

MATRIX TWO. SELECTIVE OVERVIEW OF STUDIES (continued, 14)

(various LDCs)	Markandya & Richardson (1993?)	-Meta-analysis -Discussion	-General	-General	FINDINGS -Public expenditure cuts may intensify rural poverty and shrink ag. and env. programs, but demand reduction may reduce resource exploitation in the formal sector. -Taxation will have mixed effects, depending on subsequent public expenditure and on implicit resource use incentives. -Devaluation shifts resources toward exports. Env. effects depend on specific products and production practices induced. Both resource exploitation and conservation incentives are introduced. Increased import prices for env. damaging inputs will discourage their use. -Trade liberalization will have mixed ag. env. effects depending on changes in land use, but may facilitate efficient technology imports in ag. & industry. -Pricing policies(controls, subsidies, etc.) will have positive effects insofar as they reflect env. externalities and remove env. damaging distortions. -Financial reforms have mixed effects, depending on responses in savings and investment. Above criteria apply to consumption/production responses. -Land reform will promote sustainable practices if tenure security is established and may reduce encroachment if distributed to poor. -Research and extension will enhance land management and communicate some benefits of freer markets to rural agriculture. -Project investment policy effects depend on env. nature of projects.
(various LDCs) 1979-1987	Warford, Schwab, Cruz & Hansen (1994)	-Historical -Discussion	-General	-General	FINDINGS -Structural adjustment is a necessary and perhaps sufficient condition for environmentally sustainable development. -The environmental failings of early-80s SAPs have been addressed - and many reversed. -MDB staff require training in the interplay of macroeconomics, adjustment, and the environment. -Policymakers need to be more aware of the physical and cultural context in which SAPs are implemented. -Government policy failure currently inhibits the environmentally beneficial potential of SAPs. -Priority must be given to policies that address economy and environment simultaneously.

Abbreviations and Acronyms

CGE	Computable General Equilibrium (Model)
GATT	General Agreement On Tariffs And Trade
HIID	Harvard Institute For International Development
IMF	International Monetary Fund
LP	Linear Programming (Model)
MDB	Multilateral Development Bank
NGO	Non-Governmental Organization
OECD	Organization For Economic Cooperation And Development
PE	Partial Equilibrium (Model)
PIRG	Public Interest Research Group
PPP	Polluter Pays Principle
SAL	Structural Adjustment Loan
SAM	Social Accounting Matrix
SAP	Structural Adjustment Program
SECAL	Sectoral Adjustment Loan
WB	World Bank
WWF	World Wildlife Fund

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4

Development Strategy, Macroeconomic Policies, and the Environment

William Postigo

In developing countries, important policy changes have been implemented as part of structural adjustment programs (SAPs), and this has attracted, in recent years, increasing concern with the impact that macroeconomic policies have on the environment. Through the conditionality involved in SAPs, the International Monetary Fund (IMF) and the World Bank have promoted a significant change in the strategy of development pursued by many developing countries. This new strategy has two essential components: first, the change from inward-oriented (import substitution) policies to outward-oriented (export-led) policies of economic development and, second, the radical change in the role of the state from being an active to being a much more passive participant in managing the development process. This radical change has been accompanied by the preponderance of the private sector in a context of free market–oriented economic policies. The implementation of SAPs has also taken place because the IMF and the World Bank have exerted strong pressure on developing countries to comply with servicing their external debt.

The application of SAPs in developing countries has received much criticism, mainly because of the supposedly negative impact it has had on the poorest populations of the countries that have tried to pursue these policies. Some critics have gone beyond this to argue that the macroeconomic policies included in SAPs have had a negative impact on the environment.

In discussing the impact of SAPs on the environment, a distinction is made between macroeconomic and institutional policies. On the one hand, macroeconomic policies consist mainly of the management of the foreign exchange rate, the interest rate, and the public sector budget. Institutional policies, on the other hand, mainly define the roles that the private and public sectors will play in the selected strategy of development. Macroeconomic policies must also be differentiated from sectoral (or specific) economic policies. Both are economic policies, but macroeconomic policies set the general environment for economic activities, while sectoral (or specific) policies aim to benefit or to discourage specific economic activities, specific locations or regions, and specific entrepreneurial sizes.

Although adjustment lending of the IMF and the World Bank includes both macroeconomic and institutional policies, this chapter is concerned with the environmental impact of macroeconomic policies included as part of SAPs. It is argued that their impact on the environment depends on the particular situation of the country involved. However, by increasing poverty, SAPs may contribute to environmental degradation. Also, their main negative impact on the environment is the result not of macroeconomic policies but of institutional policies.

Macroeconomic policies promoted by the IMF and the World Bank include liberalization of the external sector of developing countries (such as more open international markets of goods and capital), devaluation of national currencies and reduction of tariffs, liberalization of prices and markets, abolition of subsidies and state-owned companies, and substantially reduced government intervention in the economy (fewer controls and less expenditure). Macroeconomic policies can change the relative prices of inputs and outputs and, by this mechanism, may influence environmental degradation. The discussion that follows analyzes the linkages between macroeconomic policies and the environment. Two main questions are considered. The first is whether trade liberalization, devaluation of national currencies, elimination of subsidies, and public expenditure cuts included in SAPs have had a positive or negative impact on the environment. In considering this question, the case of land degradation is taken as an example. The second question is the extent to which the change of strategy from inward-oriented to export-oriented macroeconomic policies has had a negative impact on land degradation.

Negative environmental impact of structural adjustment macroeconomic policies

Despite frequent statements that SAPs have a negative impact on the environment, only Cheru (1992) has provided evidence to support this view. He argues that SAPs not only have failed to improve the socioeconomic situation of the countries involved but also have accelerated environmental degradation. "Adjustment programs, presumably designed to correct domestic imbalances, have failed to tackle the systemic factors that stifle production and distribution. Instead, these programs redirect available financial and productive resources toward export production in order to generate foreign exchange to pay external creditors" (Cheru 1992, p. 499).

Cheru's main argument is that by putting valuable agricultural resources at the service of export markets in countries that are not self-sufficient in food, enormous pressures are created for local people to overexploit marginal land. He argues that the push to stimulate the export sector of developing countries has been negative for the environment. However, he fails to provide a detailed analysis of the environmental impact of macroeconomic policies such as devaluation or trade liberalization or the elimination of subsidies. He does not analyze the links between the environment and the macroeconomic policies embodied in SAPs and fails to demonstrate his main contentions.

Positive environmental impact of structural adjustment macroeconomic policies

In contrast with analysts who fear that SAPs have a negative impact on the environment, Hansen (1990), Repetto (1989), and World Bank (1992) argue that SAPs have a positive impact on the environment:

- Government policies encourage an even more rapid environmental degradation than the market alone, not only because policies fail to reflect the true opportunity cost of resource use but also because subsidies, taxes, and market interventions artificially increase the profitability of activities that result in serious resource degradation (Repetto 1989).
- Export-oriented agricultural policies are positive for the environment because, with some exceptions such as groundnuts and cotton, export crops tend to be less dangerous to soils than basic food crops (Repetto 1989).
- Market liberalization favors commercial crops so that even with nonperennial crops—because commercially oriented organizations are actively involved in ensuring crop rotation and promoting good husbandry—promotion of markets should not damage the environment (Hansen 1990).
- Higher agricultural prices increase the farmer's incentives to practice soil conservation (Hansen 1990).

Sebastian and Alicbusan (1989) have presented evidence to support their perspective. However, other arguments question this view:

- Although subsidies to pesticides and fertilizers stimulate their overuse, with serious health and ecological risks, and subsidies to chemical fertilizers are an incentive to forgo soil conservation practices in favor of costly inputs, subsidies to pesticides and fertilizers do not have a significant impact on the environment in countries where the application rates are too low. This is the case of pesticides in Argentina and Colombia and of fertilizers in Sub-Saharan Africa (Sebastian and Alicbusan 1989). In these countries, removing the subsidies to chemicals could be counterproductive to increasing productivity and consequently to improving soil management. Malawi has also been cited as an example of this case (Mearns 1991, p. 10).
- Repetto (1989) argues that credit subsidies favor capital-intensive forms of agriculture and the displacement of labor in countries where, due to population pressure, labor displacement puts marginal lands under even greater pressure. However, there is also a problem of scale. On the one hand, the environmental effect of subsidized credit depends on whether it favors rich landowners or poor landowners and landless rural people. "Subsidized credits for establishing large cattle ranches and acquiring livestock in forest regions in Brazil and other Latin American countries have caused extensive environmental damage" (Sebastian and Alicbusan 1989, p. 17). On the other hand, lack of agricultural credit, by allowing the persistence of rural poverty, can equally foster environmental damage. "The obvious recourse for poor and landless rural populations lacking credit to purchase adequate inputs, or to practice conservation cultivation, is slash and burn agriculture, bringing marginal lands to the point of soil exhaustion, and irreversible environmental damage" (Sebastian and Alicbusan 1989).

- There is no reason to believe that export crops of developing countries are mainly tree crops. Even if they were, the use of land for export crops would require other land to be dedicated to food crops, and pressure on marginal fragile lands might be unavoidable. Moreover, policies to promote exports such as devaluation do not discriminate according to the type of crop. Devaluation, for instance, benefits all tradable crops because it also raises the price of imported competitive foodstuffs.
- The argument that higher agricultural prices are an incentive to practice soil conservation has been contested by Barrett (1989).
- Reducing the government expenditure involved in SAPs usually affects the capacity of the government to control environmental degradation. Frequently, budget cuts have directly reduced environmentally beneficial programs.

An alternative view of the environmental impact of structural adjustment macroeconomic policies

In contrast with the conflicting views of whether SAPs have a positive or negative impact on the environment, a third view argues that their impact cannot be predicted. Reed (1992) argues that "the impacts on the environmental sector are likely to be random and therefore mixed, that is, sometimes structural adjustment policies complement environmental goals; in other cases, they conflict and environmentally damaging effects can be observed" (Reed 1992, p. 149).

Similarly, based on the case of Malawi, Mearns (1991) argues that it is impossible to form any judgment as to the probable net effect on the environment of SAPs. Mearns points out that the effect of structural adjustment policies in one direction might be compensated by other effects in the opposite direction. An example of this is the case in which eliminating fertilizer subsidies that are used at low rates in certain locations may work against price incentives that seek to increase productivity and, consequently, against the improvement of soil management practices. In addition, price incentives may induce new production at the margin on erosive soils, with possible negative consequences such as deforestation through land clearance for agriculture and soil erosion. Another example is the case of public budget cuts. "Allocations of government budget to environmental protection and resources management are likely to be cut as a result of structural adjustment programs, but so are allocations for improved commercial access to forest land such as rural road construction which should, other things being equal, slow the rate of deforestation" (Mearns 1991, p. 11).

Although the analyses of both Reed and Mearns reach a right conclusion with regard to the indirect impact of macroeconomic policies and the specificity of the effects in a particular country, they both miss two significant, potentially negative impacts that SAPs may have on the environment: first, SAPs may increase poverty in developing countries due to the pressure to service the external debt; and second, the institutional weakening of the state may impair the national capability to regulate and to enforce environmental controls.

The assessment of the impact of SAPs in developing countries can be divided into three aspects. The first is their impact on economic development and welfare enhancement. Many countries that have applied SAPs have experienced economic stagnation and great suffering on the part of the poorest parts of the population, which seem to be the result of the extraordinary effort made, under pressure from the International Monetary Fund and the World Bank, to service the external debt. If a link between poverty and environmental degradation is assumed, it could be concluded that, by increasing poverty, SAPs have had an indirect, negative impact on the environment. However, it could also be argued that the previous policies equally failed to solve the problem of poverty and that the actual impact of SAPs on the environment does not amount to a change in tendency.

A second aspect to be considered is the effect of institutional policies, which usually lead to a significant weakening of the state. If it is agreed that environmental control requires an important role for the state, it could be concluded that SAPs have (or will have in the near future) a negative impact on the environment. This does not neglect the participation of private institutions such as local or professional organizations. But, even if private institutions play a significant role in environmental management, the state is still needed to monitor their participation. The relevant point here is that the state should perform the functions of an environmental regulator; if the state does not, in fact, do so adequately, it should be strengthened. The bias within SAP policies against the state has impaired the national capability of developing countries to manage their natural resource base properly.

The third point to be considered is whether the export-led strategy of development and the corresponding macroeconomic policies promoted by SAPs are necessarily damaging to the environment. In the next section, a model is presented to analyze the environmental impact of macroeconomic policies, such as devaluation.

A model for analyzing the impact of devaluation on natural resource use

The following model was developed by Girma (1992) to analyze the macroeconomy-environment linkages.

Household utility maximization function: (4-1)

$$\text{Max } U = u(g, s, m, H-\underline{l})$$

$$\text{s.t. } P_g g + m + P_s s \leq w\underline{l} + \bar{m} + t + \pi$$

Demand for goods:
(4-2)
$$g = g(P_g, P_s, w, m + t + \pi)$$

Demand for environmental goods and services:
(4-3)
$$s = s(P_g, P_s, w, m + t + \pi)$$

Labor supply:
(4-4)
$$\underline{l} = \underline{l}(P_g, P_s, w, m + t + \pi)$$

Demand for savings:
(4-5)
$$m - m' = \Delta m(P_g, P_s, w, m + t + \pi)$$

Firms' profit-maximization function:
(4-6)
$$\text{Max } \pi \quad \text{s.t. } Q_g = A(L, K, s)$$

Output supply:
(4-7)
$$Q_g = Q_g(P_g, w, r, P_s)$$

Labor demand:
(4-8)
$$L_g = L_g(P_g, w, r, P_s)$$

where
g, s = consumption of goods and environmental services (natural resources), respectively
m = holdings of real money balances at the end of this time period
m' = money balances at the beginning of this period
$(H - l)$ = leisure time, given H, the total labor time available at the household, and l, the actual labor use
P_g, P_s = prices of g and s, respectively
w = wage earnings
t = government transfers
π = profits
L = labor demanded
K = capital demanded
r = opportunity cost of capital.

Figure 1 Equilibrium in the market for goods and environment

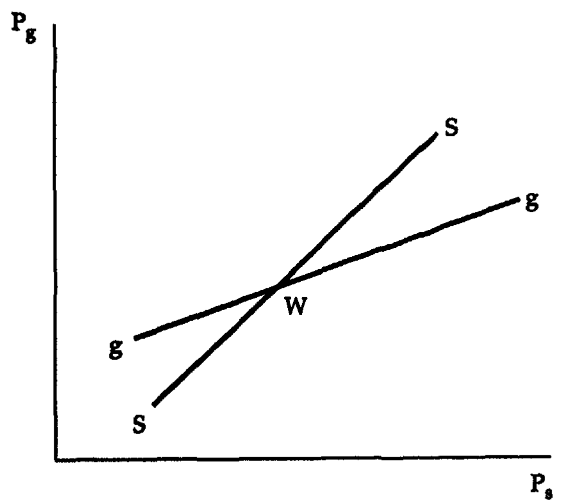

Figure 2 Effect of devaluation on natural resource use

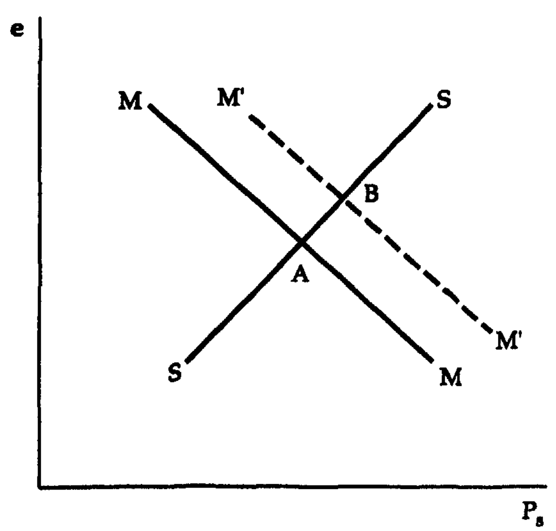

Figure 4-1 depicts equilibrium in this model (Girma 1992, p. 533). This framework allows Girma to analyze the impact of changes in economic policies, such as subsidies for agricultural inputs or monetary contraction, on the equilibrium in the markets for goods, environmental services, and labor. Here the impact of devaluation can be analyzed by adapting equations 4-6 and 4-7 and adding equations 4-9 and 4-10.

In equation 4-6, imports (M) can be included as another input to production:

(4-6a) $$\text{Max } \pi \quad \text{s.t. } Q_g = A(L, K, s, M)$$

Then, equation 4-7 becomes:

(4-7a) $$Q_g = Q_g(P_g, w, r, P_s, e)$$

where e stands for the foreign exchange rate expressed as units of local currency per U.S. dollar.

The demand for foreign exchange is represented by:

(4-9) $$M_g = M_g(P_g, w, r, P_s, e)$$

and the supply of foreign exchange is represented by:

(4-10) $$E = E(P_g, P_s, w, e)$$

In figure 4-2, the MM locus represents the combinations of e and P_s that equilibrate the foreign exchange market. The slope of MM will be negative. This is because an increase in P_s will cause an increase in the price of the final good and a decline in the demand for it. The demand for imports (another input) will fall and, with this, so will the price of foreign exchange. The points above the ss locus represent excess demand for s, and the points below represent excess supply of s. However, the points above the locus MM represent excess supply of foreign exchange, and the points below represent excess demand of foreign exchange. The effect of devaluation on the scale of natural resource use can be analyzed within this framework. Figure 4-2 shows what will happen. Devaluation is represented by shifting the locus MM to the right.

Starting from point A, the new equilibrium will be reached at point B, with an increase in P_s. Devaluation will make domestic production more competitive and, with elastic domestic supply and external demand, the increased exports will cause an increase in natural resource use. As a result, P_s will rise.

The increased use of natural resources may or may not be sustainable. If, for instance, additional land is used by clearing forests or taking up marginal or fragile lands, this may not be sustainable. However, rational forest exploitation, or increased productivity by using better management practices, will be sustainable and will cause no environmental damage. There is no a priori reason to think that a more intensive use of natural resources will be less sustainable, and sustainability will depend on the particular situation of the country and the way in which natural resources are managed.

Moreover, if domestic supply is inelastic and agricultural output is not responsive to price changes (Lipton 1987; Beynon 1989), the increase in natural resource use will not be significant, because the price incentive of devaluation will not result in increased production and exports. However, if supply is elastic but external demand is inelastic, the additional earnings of increased exports and natural resource use will not be significant either. In this case, the national effort to intensify natural resource use will not be worthwhile. However, despite the arguments of Lipton and Beynon, the elasticity of domestic supply and external demand can be quite different depending on the product and the country involved. There are important differences between Latin America and Africa and between both regions and Asia, and countries even differ within these regions. Therefore, the actual impact of devaluation can significantly vary according to the particular situation of the country involved. However, in the cases where the earnings of increased exports are not significant, the commitment to pay the external debt can place excessive pressure on the natural resource base.

If the foreign exchange market is flexible, devaluation can only hold if there is excess demand for foreign exchange, otherwise devaluation will cause excess supply of foreign exchange and an equilibrating decline of e. In this case, also, the government would not need to devalue, since the market by itself would react by increasing e to any excess demand of foreign exchange. However, the use of exchange rate controls has been widespread in developing countries, frequently giving place to overvaluation of national currencies. This has prevented free movement of the exchange rate with the result that devaluation has only been used in times of acute balance of payment crises.

But, devaluation usually has more effects than those described above. Often, devaluation causes the economy to contract due to the negative impact on real wages. Contraction occurs because consumption decreases as a result of the fall in real wages. In figure 4-2, this economic contraction can be represented by an upward shift of the ss locus (not shown here). The decrease in P_s will occur because the demand for natural resources declines as the economy contracts. In this case, the price of natural resources could fall to an even lower level than the initial one, depending on the extent of the economic contraction, which, in turn, will depend on the specific characteristics of the economic structure of the country involved. However, if the foreign exchange is fixed at the new level in point B, the natural resource base will be poorly exploited.

With a fixed money supply, the effect of devaluation on the general price level will also cause a contraction of real money balances, thereby reinforcing the contraction of the economy caused by the fall in real wages.

The effect of changes in the terms of trade is not considered here. However, deterioration of the terms of trade, other things being equal, will shrink the supply of foreign exchange, causing a rise in the exchange rate with the results analyzed above.

Therefore, the effects of devaluation on natural resource use are mixed, and prediction of the impact needs to be based on knowledge of the particular situation of the country involved.

Conclusions

It has been shown that the impact on the environment of export-oriented macroeconomic policies, particularly devaluation, depends on the particular situation of the country and perhaps even on that of particular locations within the country. Export promotion may be positive for the environment in the case of some crops, while in that of others it may be environmentally damaging. Similarly, subsidies to inputs and credit may also be positive in certain countries and regions (and for some farmers) and negative in others. This means that even if it is agreed that governments have pursued erroneous policies, there is no guarantee that the market alone will do any better. Therefore, careful sectoral government policies are still needed in order for environmental management to improve, although a change is also needed in current policies that damage the environment. Such change requires institutional capacity of the state to implement and monitor environmental policies efficiently and to enforce controls.

However, in this regard it can be argued that SAPs have a negative impact on the environment. Public expenditure cuts that form part of SAPs have been aimed at lowering aggregate demand, but because they are not evenly distributed, their impact differs from one program to another. Sometimes they favor environmentally beneficial programs such as energy conservation, land conservation and improvement, and research and extension services. But, in general, they significantly affect environmental control activities. Moreover, austerity programs such as cuts in public sector wages, in allocations for food subsidies, and in public sector investments increase poverty and, correspondingly, the environmental degradation associated with poverty and subsistence agricultural practices (Sebastian and Alicbusan 1989).[1] Government expenditure on environmental protection and resources management is likely to be one of the first targets of budget cuts. But, perhaps the most negative impact of SAPs is the institutional weakening of the state that occurs as a result of budget cuts. These reduce the capability of the state to enforce controls and regulations that are important instruments of environmental policies. This means that even if current policies were to change, the state still has an important role to play in environmental control, particularly because environmental protection requires sectoral (or specific) economic policies. The arguments about inefficiencies of the state are not reason enough to dismiss the state's role, rather these arguments justify a reform that strengthens—rather than weakens—the state's enforcement capacity.

The two questions posed at the beginning of this chapter can be answered now. First, it cannot be demonstrated that macroeconomic policies of SAPs have a positive or negative impact on the environment, because the links between macroeconomic policies and the environment are indirect and therefore very difficult to substantiate. However, sectoral and specific economic policies, and the institutional context in which these policies are implemented, are more important than macroeconomic policies in determining the extent of environmental degradation. Particularly crucial is the institutional capacity of the state to implement with enough precision the targeted economic policies that are compatible with protection of the environment and to enforce environmental regulations.

Second, there is no evidence that the change to an export-oriented strategy of economic development necessarily brings about greater environmental damage.[2] Indeed, in most cases, the change to a strategy of development that emphasizes the role of the export sector has been a consequence of the dramatic failure of previous inward-oriented development policies. As a result of such policies, the export sector was neglected (high tariffs and overvalued national currencies shifted relative prices against export-oriented activities), resulting in huge external imbalances. In this regard, the external debt crisis triggered a structural tendency to maintain an external imbalance—a tendency that had been recognized long before—and led most developing countries to look for a new strategy of economic development. This means that the change of strategy was already on the agenda of many developing countries and that, indeed, devaluation and correction of widespread price distortions were unavoidable because the macroeconomic disequilibria were so large. The problem with SAPs promoted by the World Bank and the IMF is that they not only have fostered a change of development strategy but also have put strong pressure on indebted countries to comply with the service of their external debt. In this way, SAPs have pushed developing countries to make an effort far beyond their real capabilities, with the result being the acute impoverishment of their lower-income populations and the institutional collapse of the state. The need to increase foreign exchange earnings may have also exerted pressure on the natural resource base of some developing countries.

Notes

1. Girma (1992) argues that the resulting slowdown of economic activity caused by contractionary policies prescribed in SAPs also reduces the scale of natural resource exploitation.
2. However, if this strategy is successful, and there is economic growth, the scale of resource use will increase.

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5

Macroeconomic Policies, Second-Best Theory, and the Environment

Karl-Göran Mäler and Mohan Munasinghe

In recent times, environmental degradation has emerged as a major threat to economic development and sustained improvements in human welfare. For industrial countries, where the quality of life has hitherto been measured mainly in terms of growth in net material output, pollution in particular is recognized as a serious threat. For developing countries, where economic development and poverty alleviation take center stage, both pollution and natural resource degradation are seen as serious problems.

Decisionmakers worldwide are searching for sustainable development strategies that will permit continuing improvements in the quality of life at a lower intensity of resource use, thereby protecting productive assets for future use. Sustainable development necessarily involves the pursuit of economic efficiency, social equity, and environmental protection. In particular, it requires policies and projects to be designed and implemented in such a way that environmental degradation (much of which hits the poor the hardest) is anticipated and minimized, rather than just reacted to after the damage has occurred. To the extent that macroeconomic policies have major economic and social impacts, it is particularly important to understand the linkages that give rise to such effects.

As the scale of human activities has grown, the evidence of environmental degradation has also increased, forcing the development community to recognize it as a problem. In 1989, for example, the World Bank issued its guidelines for environmental impact assessment (including social aspects), thereby elevating environmental analysis to the same level of importance as the three existing aspects of project evaluation: financial, economic, and technical analyses. Cost-benefit analysis, which seeks to assess project costs and benefits, is the key element in economic evaluation. Benefits are defined by how a project enhances human welfare. Project costs are measured in terms of opportunity costs—the benefits forgone by not using scarce resources in the best-alternative present or future application. In particular, recent advances in valuation of environmental (and social) impacts permit these concerns to be incorporated more effectively into project decisions—in the World Bank's case, potentially affecting an annual pipeline of more than 200 investment projects worth more than $11 billion.[1] Continued progress in this area is extremely important, given that conventional development projects often have serious environmental effects.

However, economywide policies (both macroeconomic and sectoral) frequently have much more powerful environmental effects than mere project-level investments. Some progress has been made in tracing the environmental consequences of sectoral policies involving, for example, energy, water, or agricultural pricing. However, the impacts of broad macroeconomic reforms (such as exchange rate devaluation, trade liberalization, privatization, and other fiscal and monetary stabilization policies) on natural resource and pollution management, are far more difficult to trace—thereby hampering efforts to design better sustainable development strategies. One key example is the World Bank, where the general lack of knowledge about links between economic policies and the environment has impeded attempts to incorporate environmental concerns into economywide or policy-based lending—the second largest use of Bank resources (about $5.8 billion annually or 27 percent of total lending). It has also hampered efforts to develop more effective national environmental action plans (which are prepared by borrowing countries, with Bank assistance, to help determine priority activities that address national environmental issues).

A recent empirically based study of economywide policies and the environment (Munasinghe and Cruz 1994) indicates that the effects of such policies on the environment vary, because they were originally intended to address nonenvironmental issues (such as economic growth or poverty alleviation). These authors conclude further that the removal of major price distortions, promotion of market incentives, and relaxation of other constraints (which are among the main features of adjustment-related reforms aimed at improving economic efficiency and productivity) generally lead to environmental gains as well. For example, reforms to improve the efficiency of industrial or energy-related activities could reduce both economic waste and environmental pollution. Similarly, addressing the problems of land tenure and access to financial and social services not only yields economic gains but also promotes better environmental stewardship.

More interesting, however, is another broad conclusion of this study, which cites extensive empirical evidence to show how unintended side effects may damage the environment when economywide reforms are undertaken in some areas while subsidiary policy, market, or institutional imperfections persist elsewhere. Therefore, specific additional measures are required to remove such policy, market, and institutional difficulties; these measures are not only generally environmentally beneficial in their own right but also critical complements to broader economywide reforms. A typical *policy distortion* might involve an underpriced or subsidized natural resource (such as low stumpage fees for logging) that could result in excessive extraction and deforestation, following the introduction of export promotion and trade liberalization policies. An example of a *market failure* would be where the external environmental effects of economic activities (like pollution) are not adequately reflected in market prices, thereby leading to excessive environmental damage following an economic expansion induced by successful economywide policy reforms. Finally, cases of *institutional constraints* would include poor accountability of state-owned enterprises, inadequate land titling, or weak financial intermediation, which may negate the environmental and economic benefits of economywide reforms. Other recent studies (cited in this volume) also provide evidence linking macroeconomic policies with the environment.

Much less effort has been devoted to developing a consistent and systematic theoretical model to analyze such linkages. Accordingly, in this chapter we seek to develop a basic analytical framework to trace the environmental impacts of macroeconomic policies, especially to identify where unforeseen negative environmental effects may occur and to design remedial measures. The model confirms the empirically observed and intuitively appealing conclusion that it is the *combination* of macroeconomic policies and subsidiary imperfections (policy, market, or institutional) that leads to environmental degradation, rather than macroeconomic policies alone. We show that the first-best remedy would be to eliminate the subsidiary imperfections without changing macroeconomic policies. As a corollary, we argue that many policy, market, or institutional imperfections may remain unnoticed in a relatively stagnant economy, because the resultant environmental damage is minor. However, once economic growth is induced by macroeco-nomic policy reforms, the environmental damage will rapidly worsen, and the underlying subsidiary imperfections can no longer be ignored. Finally, the chapter shows that if real world constraints prevent or delay the correction of policy, market, or institutional problems, then a second-best situation will arise. In such a case, there is justification for modifying or fine-tuning the intensity of macroeconomic policy reform to reduce environmental harm. The extent of such a trade-off between achieving broad macroeconomic objectives and minimizing more specific environmental damage will need to be determined on a case by case basis. There is also a dynamic element, to the extent that the relevant macroeconomic policies could be progressively intensified over a period of time, as the subsidiary imperfections are gradually eliminated by appropriate environmental reform. Illustrative examples are presented also from case studies in selected developing countries. Mathematical details are provided in appendixes.

Macroeconomic policies and general equilibrium theory

We begin with a brief review of the relevant theory. In microeconomic textbooks, it is often argued that environmental degradation occurs because of market failures—the prevalence of negative externalities. However, during the last five to ten years, it has become evident that government policies in many countries have contributed to an accelerating degradation of environmental resources. Perhaps the most obvious example of this is the devastation of the environment in the former Soviet Union. One can hardly blame markets for the mismanagement of resources in a country where markets did not play an important role. Instead, decisionmakers must be blamed for this allocation failure. This is true in many other countries too, even if the market is the basic mechanism for allocating resources. Thus, policy distortions are another source of allocation failures. We may extend this list of reasons underlying allocation failures to include institutional constraints—for example, the inability of governments to define property rights adequately or to enact and enforce environmental legislation to protect the environment.

Another idea that has been discussed more during recent years is that of *macroeconomic policy failures*. The idea here is that macroeconomic policies may have unintended side effects—positive as well as negative—on the environment and that these side effects should be considered when policies are designed. This issue is analyzed and discussed in this chapter. We start with a theoretical discussion in which we explore the reasons underlying the existence of such macroeconomic policy failures.

A simple example involving monetary policy and wage stickiness

The first fundamental theorem of welfare economics may be elucidated as follows: in an economy that is perfectly competitive and in which all goods and services can be assigned property rights and therefore be traded on markets, the resulting equilibrium is Pareto efficient. This means that in a market equilibrium, in which all goods and services are tradable, it is impossible to improve the welfare of any economic agent without impoverishing someone else. However, this result is less interesting than it seems because we do not know whether a competitive equilibrium exists or not. Furthermore, the resulting distribution of goods and services among households may be very inequitable. Both these remarks are answered by the second theorem of welfare economics: if all goods and services are tradable, if the economy is convex,[2] and if the economy is continuous,[3] then any Pareto-efficient allocation of resources can be obtained as a competitive equilibrium after the initial endowments have been redistributed in a socially acceptable way.

Obviously, these theorems do not depict reality, but they are immensely useful in discussing the consequences of macroeconomic policies. First, note that given the strict assumptions of the second theorem, there is no role for macroeconomic policies, except possibly that of redistributing initial endowments. Because we do not investigate distributional issues in this discussion, let us neglect this otherwise potentially very important role. However, the economy described by the assumptions in the theorems is really a barter economy. To make macroeconomic policies meaningful, we assume that a good called money is accepted as a mean of payments in all transactions.[4] Furthermore, we assume that the money supply is controlled by the government. Still, the government has no role in carrying out macroeconomic policies. Because all the markets function perfectly, the only thing that the government should do is to keep the money supply constant (but even if the money supply changes, that would not matter because all transactions are in real terms).

However, let us now assume that one central market does not operate smoothly enough; for example, the labor market is characterized by sticky wages. The reasons for these sticky wages are not relevant to this discussion. They may be due to union monopsonies or to insider-outsider relations or to any other realistic cause. But the existence of sticky wages means that this single market in an otherwise perfect economy will not equilibrate automatically, and there may be unemployment or excess demand for labor with ensuing inflationary pressures.

With sticky wages, macroeconomic policies now have a clear role. For example, if the initial situation is one with unemployment, an increase in money supply will tend to increase all monetary prices of goods and services outside the labor market, while nominal wages will remain unchanged. The result will be a fall in the real price of labor, and if the increase in the money supply is adjusted until the real wage rate reaches the competitive equilibrium level, full employment will be restored.[5] Exactly the reverse procedure of decreasing the money supply will be the appropriate macroeconomic policy response, if the economy is starting from a situation of excess demand for labor.

Thus, in this simple model, by using monetary policies, the government can always maintain full employment, by increasing or decreasing the money supply. Furthermore, this managed full employment equilibrium will correspond to a Pareto-efficient allocation. The monetary policy will be neutral vis-à-vis the allocation of resources (yielding the same outcome as in the case where the labor market equilibrates automatically).

Let us now introduce another distortion in the economy—one that affects the use of environmental resources. This distortion may be a traditional externality of the kind that is discussed in elementary or intermediate microeconomic textbooks. For example, the government may allow plants to emit pollutants into the air without simultaneously compensating the victims of the ensuing air pollution. Such externalities are basically due to the absence of well-defined property rights (see Coase 1960 for an illuminating discussion of the case in which property rights are well defined). Let us assume, therefore, that there is at least one environmental resource for which property rights are poorly defined. This situation may arise for several reasons. First, it could be due to the inherent difficulty or impossibility of defining individual property rights. For example, because clean air in a town is shared by all inhabitants living there, it is impossible to define individual rights to clean air (which is now a public good). Second, the government may be unwilling to define property rights for the resources. This situation is quite common. For example, in many countries, the land tenure system is such that an individual owner of land cannot be sure of reaping all of the benefits from his own land but has to share the benefits with others. The land tenure regime also may not ensure that the tenant has rights to the land in the future, which reduces his incentives to manage the land in an efficient way. In some cases, the land originally may have been managed by the village or the tribe collectively (that is, as a common property resource) in an efficient manner. Subsequently, this management system could have eroded because of instabilities and external pressures so that either the social norms controlling the use of the resource eroded or the system became an open-access common property resource. The result is that after being efficiently managed, the resource now, because of poorly defined rights, becomes overexploited.

We now face a situation where there are (at least) two deviations from full optimality or first-best allocation of resources—labor market failure and resource failure. This is the classic case of a second-best situation. Should we try to manage the money supply so that full employment is restored, assuming that we can do nothing about the environmental resource failure? According to the theory of second best, it is not socially optimal to equilibrate the labor market given the failure to allocate the environmental resource efficiently.[6] Assuming, then, that the government can do nothing with the failure characterizing the environmental resource, it is not socially desirable to use monetary policy to equilibrate the labor market! This is what we mean by the concept of macroeconomic failure: *a macroeconomic environmental policy failure occurs when macroeconomic policies, aimed at correcting one allocation failure (usually unrelated to the environment), result, at most, in a second-best allocation because of an accompanying deterioration of the environmental resource base.*

Developing country case studies

Three recent case studies from the developing world are summarized below to illustrate how macroeconomic polices might combine with local imperfections to harm the environment.

Botswana

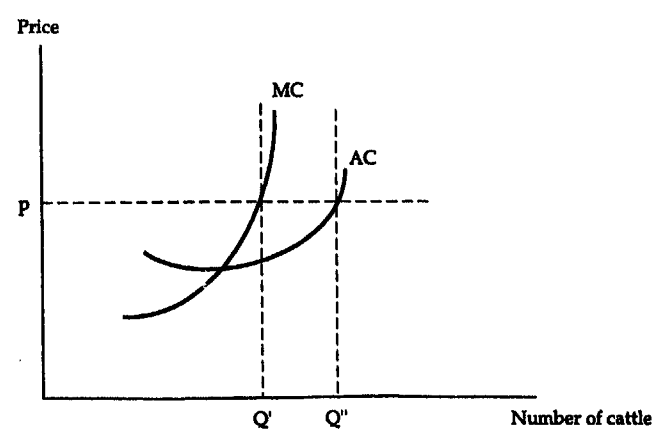
A recent study of Botswana provides an interesting example. Unemo (this volume) studies the role of changing world market prices in affecting various domestic environmental assets. One such asset is grazing land. The dominant export commodity in Botswana is diamonds, and the world market prices of diamonds determine more or less the terms of trade of Botswana. One could therefore raise the question of what the effects on grazing behavior will be if the world prices for diamonds fall. On the face of it, a change in diamond prices should be of no consequence for grazing behavior. However, taking the general equilibrium effects into account, it seems that a change in the prices of diamonds may have a non-negligible effect! Unemo analyzes this in the context of a computable general equilibrium model, with which she makes a number of policy experiments. One of these is a change in the world market prices for diamonds. Note that such a change is not a policy change, but we could, instead of studying exogenous price changes, look at changes in export subsidies that would result in effectively the same change in terms of trade.

Unemo's result is that a fall in diamond prices will increase overgrazing in Botswana and thereby impose increased environmental costs. The intuitive reason for this is that a fall in terms of trade will reduce the profits in the industry and therefore the return on capital. But if the return on capital goes down, the capital will become cheaper and this will encourage investments in cattle.

Note that if there had been effective private property rights to land (or communal ownership with strict social control over the number of cattle that members of the community are allowed to graze), this would not be a problem. Each landowner would make a comparison of costs and benefits, taking into account the damage to grazing from increasing the herd. In fact, each cattle owner would bring as many cattle as possible to his grazing land up to the point where the selling price of the cattle would equal the marginal cost, including the environmental damage. Thus, he would balance the environmental damage with the increased profits from cattle herding. The change in terms of trade would not lead to macroeconomic policy failure.

However, in large parts of Botswana, the grazing areas are under open-access common property regimes. Then each cattle owner would bring as many cattle to the commons as is profitable to him. Because he does not consider the damage he is inflicting on others, he will continue to add cattle to the point where price equals average cost. The average cost curve is less steep than the marginal cost curve, and the result is therefore a bigger increase in the number of cattle brought to the grazing land than would take place with private property rights. In the diagram in figure 5-1, the amount of overgrazing is measured by Q′′– Q′. Here we would have a macroeconomic policy failure. It is important to note that the lack of private property rights is basically responsible for this failure, rather than the original fall in diamond prices (or reduction in export subsidies).

Figure 5-1 Average and marginal cost curves and overgazing



Ghana

The role of institutional constraints in programs of macroeconomic reforms is examined in a recent case study of Ghana (López 1993). In this example, trade liberalization, by reducing the taxation of agricultural exports, leads to increased production incentives, while efforts to reduce the government wage bill tend to increase the pool of unemployed. Thus, the adjustment process helps to stimulate production of export crops and combines with rapid population growth and lack of employment opportunities outside the rural sector to create increasing pressure on land resources, encroachment onto marginal lands, and soil erosion. This effect on resource use is influenced by the allocation of property rights. Whether in relation to the security of land tenure of peasant farmers or to the right to extract timber of logging companies, uncertainty normally results in environmental degradation. In Ghana, as in many regions in Africa, agricultural lands are governed by traditional land use institutions, and farms are communally owned by the village or tribe. These common property regimes may have been sufficient to ensure sustainable use of agricultural lands when populations were much smaller and fallow periods were long enough to allow land to regain its fertility. However, such traditional arrangements have been overwhelmed ultimately by economywide forces, resulting in reduced fallowing, loss of soil fertility, and environmental decline. The best remedy would be to revise the land tenure regime to resist externally induced pressures.

This study analyzes the effects of ongoing trade liberalization and public employment reduction on agricultural productivity and land use in the country's western region. A noteworthy outcome of the policy simulations is that the main source of supply response in agriculture is the expansion of cultivated area rather than agricultural intensification. Biomass, measured in terms of the proportion of land under forest cover, is an important factor of production, contributing an estimated 15 to 20 percent of the value of agricultural output. This compares with the contribution of "conventional" factor inputs: 26 percent for land cultivated, 25 percent for labor, and 26 percent for capital. Because the share of agricultural output in national gross domestic product (GDP) is about 50 percent, the contribution of biomass to national income is about 7.5 percent. Thus the stock of biomass is an important determinant not only of agricultural production but also of GDP.

In the agricultural system prevalent in the area, a large proportion of the land available in the village is reserved exclusively for the use of villagers. The system is consistent with shifting cultivation because the individual has exclusive rights to the land actually being cultivated, but once the land is left fallow, it can be reallocated by consensus and consent of the village chief. Under these conditions, biomass is already being overexploited through a more than optimal level of land cultivated. Fallow periods appear to be too short, and the stock of the environmental resource is below socially optimum levels. The study finds that increasing agricultural prices or reducing wages causes an expansion in the cultivated area, with the direct effect of increasing output. For example, a 10 percent increase in land cultivated leads to a 2.7 percent increase in the direct output effect. However, such an increase in cultivated area leads to a reduction in fallowing, and total biomass declines 14.5 percent. This, in turn, leads to a 2.5 percent loss of sustainable agricultural productivity. Thus, the net effect of expanding the area cultivated (2.7 percent direct output effect less 2.5 percent biomass loss effect) is still positive, but a mere 0.2 percent—many times smaller than the direct effect alone. In addition to policy changes, other factors contribute to expansion of cultivated area: large family size, availability of capital, and the presence of migrant populations in the area.

The results suggest that, in general, economywide price and wage policy reforms that do not include changes in land management practices will have very limited impact on national income, once the existence of land quality effects is considered. For example, the effects of further reducing implicit taxation of agriculture are in general ambiguous, while the effects of import liberalization are perverse. However, reducing the fiscal deficit (through reducing public employment or wages) has unambiguously positive effects on agriculture and national income.

If agricultural price responsiveness relies less on land expansion and more on intensification, the policy implications of trade liberalization would be more favorable. Currently, Ghana is gradually improving its agricultural research and extension service, and this could result in future yield increases. However, it is likely that without institutional reforms and with land still available for cultivation, a significant component of the supply response will continue to be based on the expansion of agricultural area. This would have unfortunate implications for sustainable agricultural development. Indeed, in the area studied in the western part of the country, the economywide policy reforms lead to an expansion of cultivated area and thus a decline in fallowing. Environmental and socioeconomic data indicate that in terms of its contribution to agricultural production, fallowing (measured as the ratio of forest biomass to cultivated land) is comparable to other more conventional inputs, such as area cultivated, labor, and capital. Explicitly incorporating the effect of this environmental change reduces the otherwise substantial positive effect of the reform on agricultural output. The assessment concludes that complementary institutional reforms will be needed to ensure that the current income improvements from adjustment reforms will be sustainable.

Morocco

The Morocco study focuses on the linkages between macroeconomic policies and how the existing water allocation system has led to suboptimal and unsustainable patterns of water use (Goldin and Host 1994). Specifically, low water charges (coupled with ineffective collection of these charges) have artificially promoted production of water-intensive crops such as sugarcane. Thus, rural irrigation water accounts for 92 percent of the country's marketed water use. At the same time, irrigation charges cover less than 10 percent of the long-run marginal cost, and the corresponding figure for urban water tariffs is less than 50 percent. Given these policies, it is not surprising that a water deficit is projected for Morocco by the year 2020, notwithstanding the fact that, by the same year, water sector investments will be high.

The study, however, goes beyond the traditional sectoral remedy of proposing an increase in water tariffs. It links sectoral policy reforms with ongoing macroeconomic adjustment policies, namely the complete removal of nominal trade tariffs, and analyzes the overall effects of both sets of reforms. As a consequence of the trade reforms, prices of sugar, cereals, oilseeds, meat, and dairy products, among other things, would decline to world levels from their current protected levels. Further, a *simultaneous* introduction of trade and water pricing reforms would imply increased input prices and a decline in output prices. A computable general equilibrium (CGE) model is used to trace the impact of these reforms on output, consumption, imports, exports, and the use of factors of production (including water) by the different sectors in the economy.

To separate out the effects of the sectoral and macroeconomic reforms, the study considers three scenarios: trade reform only, water pricing reform only, and a combination of the two. In the first scenario, the only policy change is a complete removal of nominal tariffs (which in 1985 averaged 21 percent for the whole economy and 32 percent for agriculture). Similarly, in the second scenario, the only change is a doubling in the price of rural irrigation water. In the final scenario, the two policy reforms are combined.

In the first scenario, liberalization of trade alone has positive effects—there is a marginal rise in real GDP, while household incomes and consumption post significant gains as import barriers are reduced, exports become more competitive, domestic purchasing power rises, and resources are allocated more efficiently across the economy. The two major drawbacks, however, are that elimination of tariffs leads to budgetary deficits and domestic water use increases substantially due to the expansionary effects of liberalization—resulting in increased environmental pressures.

In the second scenario, other things being equal, reforming water prices alone reduces water use significantly—by 34 percent in rural areas and by 29 percent for the economy as a whole. This is as would be expected. This achievement of static efficiency, however, is acquired at an economic cost—real GDP falls by about 0.65 percent, and incomes and real consumption of both rural and urban households decline by approximately 1 percent.

In the final scenario, the expansionary effects of trade liberalization are retained, but reforming water prices still induces substantial reductions in agricultural (and economy-wide) water use. Moreover, this reduction in water consumption occurs against a backdrop of growth in real GDP in contrast to the scenario involving price reform only. Thus, the combination of trade reforms and improved water pricing provides both economic and environmental gains.

Effects of taxes

There are many similar situations in which macroeconomic policies can have consequences for the environment, but the root of the problem is not directly connected to the environmental resource. When designing fiscal policies for macroeconomic stabilization, it is widely recognized that such policies carry deadweight burdens. An increase in taxes to reduce effective demand and generate government revenues generally creates distortions in the economy, especially in the case of taxes unrelated to real resource costs—such a tax increase cannot be implemented as a lump sum tax. The conventional view is that the resulting deadweight burden is due mainly to distortions in the labor and capital markets. But taxes also affect the patterns of location and the structure of production, which in general also affect the environmental resource base. In this case, the root of the problem is that taxes have incentive effects, and an increase in taxes (to solve a macroeconomic problem) therefore has a deadweight burden that includes environmental deterioration. It is obvious that, in some cases, the deadweight burden will be negative. This would be the case when the environmental resources are underpriced and the tax increase takes the form of pricing these resources. Here there are three distortions: the general macroeconomic distortion, the distortion from tax increases, and the lack of environmental pricing. With environmental taxes, the macroeconomic policy objectives can be achieved by taxes that improve the existing allocation of resources.

This situation has given rise to the idea of a green tax reform. Because taxes on conventional factors of production (labor and capital) and taxes on commodities are distortive—while taxes on underpriced environmental resources improve the efficiency of resource allocation as well as provide tax revenues—it is thought that such a tax reform should have a double dividend. The first dividend would be the improvement in the environment, and the second would be the reduction of deadweight burden from existing taxes. However, recent theoretical and empirical work has cast serious doubt on the existence of the second dividend. In fact, a green tax may increase the excess burden from existing taxes with more than the corresponding reduction achieved by lowering these taxes (Bouvenberg and de Mooij 1994).

The same arguments obviously apply also to changes in expenditure patterns. Expenditures for ensuring increased effective demand will certainly have allocation effects, and we have to argue as above. What are the effects of the increased government expenditures on the exploitation of environmental resources? They may be positive or negative, it is impossible to say a priori. But it is necessary to take these effects into account when designing the fiscal and expenditure policies.

The natural and obvious solution to these problems is, of course, to try to reduce the market failure that gives rise to the environmental degradation and thereby to improve on the second-best solution. In the example of Botswana, this result can be achieved by introducing appropriate property rights, by introducing effective environmental legislation that is enforced, and so forth. Whenever possible, this route should be followed. However, in many cases, this is not possible. For example, the root of the problem may lie in old cultural patterns that cannot be changed in the short run (as in the Ghana case), or it might lie in the difficulty of monitoring property rights or enforcing environmental protection legislation.

Furthermore, because lump sum taxes are not feasible, it follows that there will always be deadweight burdens. Ideally, the tax system should be designed to minimize the total deadweight burden (taking due account of distributional impacts). However, effects on the environment should then be included in measurement of the deadweight burden. The model in appendix 5-1 shows how that can be done in simple cases.

Summary and conclusions

Too often, economists have assumed that we live in a first-best world and have based policy recommendations on that assumption. But in fact, we live in a second-best world, and this fact gives rise to macro-economic policy failures with respect to the environment. Therefore, much needed macroeconomic policy reforms should take this into account. If it is found that the environmental side effects will be substantial, either the root causes (such as property rights problems) should be addressed or, if that is not feasible, the macroeconomic policy should be appropriately modified in order to reduce losses.

Most often, the impacts on the environment from changes in macroeconomic policies are channeled through rather complex and indirect mechanisms in the economy. In order to identify these side effects, general equilibrium analysis has proven to be quite valuable. In spite of the rather severe problems with numerical accuracy, computable general equilibrium models are at present the only tools available that can help us to identify relevant second-best problems when macroeconomic policies are developed. It therefore seems to us that an active program of amalgamating macro-economic objectives with environmental objectives could be pursued in the context of general equilibrium models.

Appendix 5-1. Model of the second-best nature of macroeconomic policies

The purpose of this appendix is to show in a formal mathematical model the second-best nature of macroeconomic policies when there are environmental externalities that are not internalized. Because the purpose is only to exemplify the second-best nature, the macroeconomic model has been chosen on the grounds of simplicity. Thus, the macro-economic model is basically the general equilibrium model analyzed by Patinkin (1965). In this model, it is assumed that individuals value real balances for various reasons (mainly to reduce transaction costs) and that the demand for such balances is determined by prices, wealth, and initial balance. Furthermore, Patinkin assumes (at least in one chapter) that wages are sticky.

Thus we will consider a disequilibrium model, in spite of the fact that such models are not considered adequate (basically because they do not explain the stickiness of wages).

Let there be a representative consumer with a utility function

$$U = U(x, E, L^s, \frac{M}{p}) \tag{5A-1}$$

where x is demand for the consumption good, E is a vector of emissions of pollutants to the environment, L^s is the desired supply of labor, M is the demanded nominal money balance, and p is the price for the consumption good. Thus $1 / p$ is the price of money. The inclusion of money in the utility functions has been severely criticized (see, for example, Arrow and Hahn 1971). However, this is not the place to discuss that criticism.

The budget constraint for the representative consumer can be written

$$px + M + T = wL^d + M_0 \tag{5A-2}$$

where w is the wage rate, L^d is the demand for labor (which in the case of wage stickiness may be different from the desired supply), and T is the lump sum tax paid by the consumer.

With a fixed wage rate, the demand for labor, L^d, must be smaller or equal to the supply of labor, L^s.

Utility maximization subject to the budget constraint (and to the constraint that labor supply must not exceed labor demand) yields the following net demand functions for goods and money:

$$\begin{aligned} x &= x^d\,(p, E, M_0, w) \\ M &= M^d\,(p, E, M_0, w). \end{aligned} \tag{5A-3}$$

Let us now turn to the supply of goods and services. We assume that production of all goods and services is characterized by constant returns to scale. The production follows the following production functions:

$$x = f(L^d, E). \tag{5A-4}$$

Note that emission of pollutants is regarded as a factor of production. Let us assume that the government is internalizing the emissions by charging the firms with q per ton emitted. The profit is then

$$\pi = pf(L^d, E) - wL^d - qE. \tag{5A-5}$$

Maximizing profits yields the following demand and supply functions:

$$\begin{aligned} x &= x(p, w, q) \\ L_i^d &= L^d(p, w, q) \\ E &= E(p, w, q). \end{aligned} \tag{5A-6}$$

Let us now consider the public sector. The government is responsible for taxing the individuals, for controlling the money supply, and for controlling the emissions to the environment. The budget in the public sector looks like

$$T + M + qE = 0. \tag{5A-7}$$

If the government has determined the marginal willingness to pay for environmental improvements and set the emissions charge equal to this marginal willingness to pay, then:

$$q = -p\frac{\partial U/\partial E}{\partial U/\partial x} = \phi(p, E, M_0, w). \tag{5A-8}$$

Here, ø gives the marginal willingness to pay for the public good as a function of the variables determining the budget constraint for the individual. By this assumption, we are assured that there will always be an optimal level of pollution.

Assume for the moment that wages are flexible so that the labor market clears. Then it follows from the model that money is neutral and a change in the money supply has no real consequences. Furthermore, the resulting allocation of resources is efficient. However, the point to be made has to do with sticky wages. Therefore assume that the wage rate is exogenously given:

$$w = \overline{w}. \tag{5A-9}$$

If w is high enough, the total demand for labor is less than the exogenously given supply, L^s, and there is unemployment. Now there is room for government macroeconomic policies. An increase in the money supply now affects the real economy. The mechanism is the conventional one. After an increase in the money supply, each individual finds himself with too high real balances, which increases his net demand for goods and services. This increases the prices of goods and services in general and thereby reduces the real money balance held by individuals and increases the output and therefore the demand for labor. It follows that the real wage rate falls, and in the end it is possible to reach a situation with full employment. However, in the process, the emissions have probably increased, and the environment has therefore probably deteriorated. This is as it should be, because the polluters are paying the marginal social cost of pollution. The gains from increasing the employment exceed the loss in environmental quality.

If the marginal social cost of pollution rises very sharply with increases in pollution, the end result is only marginal increases in emissions and the monetary expansion causes reallocations between different sectors so that less polluting sectors expand and more polluting sectors contract. In the end, full employment is generally reached.

Obviously, if the marginal willingness to pay for environmental quality is inelastic with respect to emissions and if the emissions per ton of output are very high, there may not exist a full employment equilibrium. However, we will disregard that possibility because plants always have ways of abating emissions other than reducing production.

In order to study this closer, let us depart from the assumption that the emission charge is optimal. On the contrary, assume that q is less than the marginal willingness to pay for pollution abatement. In such a situation, what is the effect of an increase in money supply? Differentiating the utility function yields:

$$\begin{aligned} dU &= U_x dx + U_E dE + U_L dL + U_M d\frac{M}{p} \\ &= p dx - q dE + w^s dL + Y d\frac{M}{p} \qquad (5A\text{-}10) \\ &= (\overline{w} - w^s) dL - (q - \overline{q}) dE + Y d\frac{M}{p}. \end{aligned}$$

The first parenthesis indicates that an increase in the demand for labor increases welfare as the fixed wage rate exceeds the reservation wage, w^s. The second parenthesis indicates, however, that the increase in pollution reduces well-being as the marginal willingness to pay exceeds the emission charge. If the emission charge would have been equal to the marginal willingness to pay, then it would obviously have been optimal to increase the money supply until the reservation wage rate equals the fixed wage rate. However, in the face of a less than optimal pollution charge, this is not optimal. In fact, the formula above says that the increase in money supply should be smaller than what would correspond to full employment. Thus, *if it is not possible to optimize the allocation rule regarding the environment, it is not optimal to try to achieve optimal macroeconomic policies.*

Notes

1. A billion is 1,000 million. All dollars are U.S. dollars.
2. That is, the production possibilities are characterized by nonincreasing returns to scale and to individual production factors, and the consumption preferences can be characterized by indifference curves, which are convex toward the origin.

3. That is, the production possibility sets are closed, and the consumer preferences can be described by ordinary indifference curves.
4. There is no need to discuss all the problems connected with introducing money in general equilibrium models. For an early attempt, see Patinkin (1965); for a critical discussion, see Arrow and Hahn (1971).
5. This is obviously a drastic oversimplification of macroeconomic theories, but as we have repeatedly stressed, this is not a discussion of macroeconomic policies per se, but of their relations to environmental failures.
6. Lancaster and Lipsey (1956) were the first to investigate the problem of second best. They posed the following question: if one of the marginal conditions for Pareto optimality cannot be achieved, is it desirable to achieve all other marginal conditions? They found that the answer is no. In fact, in order to achieve the best allocation when one of the marginal conditions cannot be satisfied, the best policy is to violate *all* marginal conditions!

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6

Environmental Impacts of Structural Adjustment: The Social Dimension

David Reed

One of the conclusions to be drawn from the World Wildlife Fund's study, *Structural Adjustment and the Environment*, is that an analytical approach that attempts to document the impact of structural reforms on the environment must take into account not only the direct economic and environmental changes but also the social dimension—in order to give a full accounting of indirect impacts on the environment (Reed 1992). A growing number of studies, including the World Bank's recent study, *Economywide Policies and the Environment* (Munasinghe and Cruz 1994), have attempted to understand the impact of economic restructuring programs on the environment by looking at the relationship between specific economic instruments and particular environmental problems. This is a reductionist and, unfortunately, incomplete approach. The linkages such an approach establishes between economic instruments and environmental problems may be accurate per se. However, conclusions derived from this approach may be misleading because they tell only part of the story. Specific instruments of economic reform programs seldom have a direct effect on environmental problems. They are transmitted through society by its changing class structure, shifting social relations, and evolving institutions. Thus, to understand the full impact of adjustment on the environment, one must first understand how structural adjustment is changing society at large, and, from that broad social vantage point, it becomes possible to interpret the environmental consequences of the reform program.

The Venezuela case study: Impact on labor markets and the environment

To illustrate the importance of this issue, consider the results of two of the country studies included in the World Wildlife Fund's second study on the impact of structural reforms on the environment in nine developing countries. The first case study is Venezuela (CENDES 1994). The Venezuelan restructuring package—the great turnaround of 1989—sought to restore macroeconomic equilibria (fiscal, external, monetary, and financial balance) and to bring prices, public utility rates, and the exchange rate in line with economic conditions. According to the officially stated objectives, these reforms would generate growth without inflation, reduce unemployment, and shift the country to an outward-oriented development path. This reform program included revitalization of the country's stagnant agricultural sector. However, after five years of implementation, the real impact of the reform process has been to induce protracted stagflation, growth of fiscal and external deficits, decline in real income, and a dramatic expansion of poverty. In fact, the major structural impact of the adjustment process has been to restructure the country's labor market.

An analysis of the environmental impacts of these macroeconomic reforms that only links the macroeconomic and sectoral instruments to the country's major environmental problems reveals three major impacts of the reforms:

- Fiscal cutbacks have led to a significant decline in public resources for environmental management and environmental infrastructure.
- Liberalization of the economy has attracted significant foreign direct investment, particularly to the extractive sector (such as gold and bauxite), that is having significant environmental impacts in the interior of the country.
- Increased reliance on oil reserves to address the country's fiscal and financial crises has postponed efforts to implement more stringent environmental controls over the petroleum industry.

By including an analysis of the social dimension of adjustment polices, a far more comprehensive and accurate picture evolves. The social dimension of Venezuela's reform program was provided by analyzing the impact of adjustment on the country's labor market. In this regard, adjustment has had the following impacts:

- Rural to urban migration has accelerated.
- Distributional inequities have grown by about 5 percent: incomes of the lower and middle classes have fallen dramatically, and the distance between those classes and the wealthy has increased to an alarming degree.
- There has been a significant increase in the number of workers earning less than the official minimum wage.
- The index of job precariousness has increased.
- There has been a relative and absolute decline in agricultural employment.

In the context of these social impacts, let us consider again the environmental consequences of macroeconomic restructuring. To the three environmental impacts mentioned above, we can add the following:

- The accelerated rural to urban migration has severely intensified urban environmental degradation and significantly increased urban health and sanitation problems.
- The urbanization process has intensified pressure on water resources in the central

part of the country and in major urban areas.

- Disregard for the agricultural sector has intensified degradation of the rural environment and agricultural lands.
- An increase in rural poverty has intensified pressure on protected areas through expanded agricultural intrusion and fishing and hunting conflicts between rural communities and the national parks system.
- Declining income in middle- and low-income neighborhoods has weakened the capacity of neighborhood associations and nongovernmental organizations to carry out their very important activities for managing local resources.

In short, adjustment has not only failed to increase economic productivity and efficiency but also reduced the standard of living of middle- and low-income groups and locked the society into patterns of mismanagement of its natural resources.

The El Salvador case study: Impact on political economy and the environment

The second example is El Salvador (PRISMA 1994). This country study illustrates how structural adjustment affects a country's political economy, which, in turn, directly affects the environment. There have been two stages in the recent macroeconomic reforms of El Salvador. The first stage was implemented by the U.S. Agency for International Development (USAID) as an integral part of the U.S. government's efforts to address the underlying economic and political contradictions that ultimately gave rise to civil war in the 1980s. As part of the broad social transformation, USAID sought two basic economic reforms during the early adjustment process: exchange rate and fiscal policy reforms. This reform package also led to the dismantling of many governmental institutions including government agencies responsible for environmental management. In the second stage, with USAID still acting as overall coordinator of the reform process, the World Bank, the International Monetary Fund, and the Inter-American Development Bank entered the reform process. These multilateral institutions financed specific reform programs that included two structural adjustment loans, trade liberalization, and financial sector and fiscal reforms. One of the main objectives of the externally financed reforms was to shift the economic base of the country away from traditional agricultural products and toward the export of nontraditional agricultural products and light industrial goods.

If traditional macroeconomic indicators were the main criteria for evaluating the reform program, the adjustment process would be declared a success. For example, inflation is down, balance of payments deficits are being reduced, foreign resources are increasing, and fiscal imbalances are being corrected. These indicators, however, are deceptive, because the adjustment process has not shifted the economy onto a more productive and sustainable basis. Consider, for example, the fact that there have been no improvement in nontraditional exports as intended, no improvement in traditional exports, and only minimal expansion in industrial capacity.

If the basic structural adjustment has not been accomplished, what then has generated the apparent improvement reflected in standard measures of economic performance? The answer, which can be summarized in the following points, is complex and disturbing.

- Adjustment has shifted El Salvador to a tertiary, service-based economy, not a more productive agricultural or industrial economy. Adjustment has helped economic elites to regain the dominant position in most profitable sectors of the economy, which are now the commercial and financial sectors.

- Recent economic expansion is occurring through a rapid urbanization process based not on industrial growth, but rather on commercial expansion and speculation.
- Improvement in economic indicators has been possible owing, in large part, to the economy's deepening dependence on the inflow of foreign capital. The sources of foreign currency are primarily worker remittances and official development assistance, which have been abundant in recent years. (It should not be forgotten that social and economic problems, particularly in the rural sector, led up to one-fifth of the country's population to migrate to other countries, particularly the United States, during the past decade.)
- Adjustment has not restructured the agricultural sector. Rather, it has consolidated existing social and economic relations in that sector, including stark social inequities and skewed patterns of landownership.

In consideration of the impact of the reforms on the county's political economy, a clearer reading of the environmental impact of adjustment becomes possible. The environmental impacts of this restructuring process include:

- Traditional land management relations and practices that lead to the deforestation of the country, serious erosion of farmlands, and contamination of soils with pesticides have remained in place. These relations promise to intensify rural environmental degradation.
- Watershed management throughout the country has deteriorated dramatically over the past decades. The reform program has consolidated social and economic relations that generated this environmental crisis, and, consequently, further degradation of watershed management can be expected in the future.
- Accelerated urban expansion and accompanying pollution are threatening to contaminate water resources throughout many parts of the country. Adjustment has encouraged the urban growth without providing for improved urban environmental management.

The earlier destruction of environmental management institutions that occurred under USAID tutelage has not been reversed. Fiscal retrenchment under adjustment coupled with the lack of political commitment, has left the country with no coherent, integrated set of institutions to address the deepening environmental crisis. In short, by failing to address underlying social inequities, by consolidating control of elites over the most dynamic sectors of the economy, by deepening dependence on external financing, and by failing to address underlying environmental problems, adjustment has not put El Salvador on a more productive or sustainable development path.

Conclusions

These two examples illustrate why the social dimension of adjustment programs must be integrated into an analysis of the impact of structural reforms on the environment. They illustrate how economic reforms change class structures and social relations in adjusting societies and how, in turn, such reforms can have negative, long-term environmental impacts. These two examples also raise questions about the viability of the World Bank's current win-win strategy. That strategy encourages policymakers to give priority to policy reforms that increase economic efficiency while also generating positive environmental changes.

The examples of Venezuela and El Salvador oblige analysts to ask what impact apparent win-win interventions have on the broader social fabric of adjusting countries that, in turn, can possibly generate negative environmental impacts. The two examples suggest that unless changes in social structures and social relations are examined adequately, win-win situations in appearance may actually consolidate underlying social contradictions and thereby aggravate already serious environmental problems.

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7

Policy Issues in International Trade and the Environment with Special Reference to Agriculture

Nico Heerink, Arie Kuyvenhoven, and Futian Qu

The increasing awareness of environmental problems with international or global dimensions in recent years has led to a growing interest among policymakers in the interactions between international trade and the environment. At the same time, it has caused an upsurge of scientific work that intends to provide a theoretical background for policy decisions on international trade and the environment. For some of the issues involved, a growing consensus seems to have been reached in the literature with respect to the most appropriate policy measures. Other issues, particularly the alleged environmental effects of trade liberalization policies, remain highly controversial.

The purpose of this chapter is to discuss some of the major policy issues in the field of international trade and the environment as well as the answers provided in the literature, using the current state of environment and trade theory. With regard to the contended environmental effects of trade liberalization, an effort is made here to develop an analytical framework that can serve as a basis for further research.

Environmental policies are discussed in the first two sections. Adoption of (theoretically sound) environmental policies generally leads to changes in trade flows, as the correction of previous market failures changes comparative advantages between countries. The introduction of environmental policies also raises a number of questions regarding a country's competitiveness, international harmonization of environmental standards and measures, and the potential role of trade measures. For analytical purposes, domestic environmental effects are distinguished from transborder or global environmental effects. The next section examines consequences of national environmental policies for international trade, followed by an examination of international environmental problems and the related use of trade measures.

Another important policy issue is the impact of trade and trade liberalization on the environment. According to the theory of international trade, free trade maximizes national and global welfare provided environmental externalities are corrected through appropriate policies (and various standard assumptions about the functioning of markets are satisfied). These corrective policy measures should be such that producers take into account the social costs of production for export.

However, for various reasons, governments often adopt policies that intervene with free trade. Moreover, until now corrective environmental policies have rarely been undertaken. Therefore, this chapter examines the potential impacts of trade liberalization on the environment by first presenting a theoretical framework. It is argued that the overall effect of trade liberalization on the environment can be positive or negative, depending on the case examined. Empirically estimated models of the different counteracting effects are needed to assess the direction and magnitude of the relationship for each case. Thus presentation of the theoretical framework is followed by examination of trade liberalization in agricultural products, which forms an important item in recent trade liberalization efforts. The outcome of recent studies that try to assess the potential environmental effects on the basis of the simulation results of agricultural trade liberalization models is reviewed and evaluated. One important element that deserves much more attention is the effect of trade liberalization on soil degradation in developing countries. This topic is discussed next. The main types of soil degradation in developing countries are reviewed, and an analysis is presented of the effects on soil degradation of price changes that result from agricultural trade liberalization. It is argued that the current controversy in ideas about whether higher prices will lead to increased soil degradation can be explained by the fact that different authors address different aspects of the relationship between soil degradation and price changes. Finally, the chapter presents policy conclusions and suggestions for future research.

National environmental policies and international trade

Domestic environmental problems can, in principle, be resolved by purely domestic policy choices. These choices are made on the basis of various considerations and priorities. Different countries have different natural resources, different natural conditions, and different environmental assimilative capacities. Furthermore, the priority given to environmental quality differs from country to country. Poor countries generally attach lower priority to environmental quality than rich countries do.

International harmonization

There is a growing consensus in the literature that, in the case of national environmental problems, international harmonization of environmental standards is neither necessary nor desirable (see, for example, Dean 1992; GATT 1992; Subramanian 1992; Verbruggen 1991). Comparative advantage is based on the existence of differences between countries: differences in resource endowments, production conditions (including technology), and consumption preferences. The gains from trade or international specialization derive from this difference. The environment is one element of possible differences between countries.

A country is considered to have environmental abundance if it has a relatively large assimilative capacity. This capacity is determined not only by the physical ability of its water, air, and land to absorb waste but also by the level of pollutants the society is willing to tolerate (Blackhurst 1977; Dean 1992).

In the eyes of domestic producers, differences between countries in their environmental policies are often regarded as unfair, because they give rise to differences in competitiveness. Lower standards abroad regarding pollution are perceived as detrimental to competitiveness. Political pressures to lower the standards at home or to eradicate any trade created by the differences in standards are the logical culmination of this line of thought. However, when the environmental problems are strictly domestic, the differences in policies are properly regarded as domestic choices reflecting, among other factors, the domestic tradeoffs between income and the environment. A country with a high preference for environmental quality should accept the consequences for its international market position. Differences in costs of production due to differences in standards can well be an additional source of gainful trade among these nations, as are any number of other natural advantages (GATT 1992, p. 29).

It is also important to recognize that, in principle, there is no difference between the unfair competition argument regarding environmental standards and arguments that could be advanced for remedial action against lax population policies, large expenditures on education, policies encouraging capital formation or the immigration of skilled labor, or other policies influencing competitive advantage (GATT 1992, p. 29; Subramanian 1992, p. 141). All these policies can favor or harm the competitive position of specific sectors within a country.

Subramanian concludes that where there are no physical spillovers, there ought to be a serious presumption against the use of trade restrictive action—be it in the form of contingent protection action (countervailing or antidumping duty), competitive subsidization, or attempts to harmonize pollution standards (Subramanian 1992, p. 142). In contrast, Daly and Goodland (1994) argue that trading rules should recognize that externalities are, in effect, environmental subsidies, which are as economically distorting and unfair as any financial subsidy. In their view, GATT (General Agreement on Tariffs and Trade) rules should discourage such eco-dumping and permit countries to protect themselves against eco-dumping by others. The analysis by Daly and Goodland neglects the presence of differences in abatement costs and differences in environmental preferences between countries. The lower the abatement costs or the lower the priority attached to environmental quality, the smaller the size of a country's environmental subsidy. Environmental standards should therefore be determined locally, and import tariffs to correct for differences in environmental standards would be misdirected instruments (see also Dean 1992; Pearson 1987). The countries that would suffer most from such protective policies are countries with a high preference for income growth and a relatively low preference for environmental quality (for example, predominantly low-income countries) and countries with relatively low abatement costs.

Although international harmonization of standards should generally not be pursued in the case of domestic environmental problems, harmonization of the form of environmental policy (principles and measures) is highly desirable. A uniform system of financing environmental measures is needed to avoid distortions in international trade that result from differences in implementation measures. The polluter pays principle (PPP) could serve as a guiding principle in this respect. Global adherence to this principle would diminish tensions between trade and the environment.

Impact on trade

What will be the impact of environmental regulation on trade? When a country unilaterally introduces environmental policy, comparative advantage in the production of the damage-intensive good will move in favor of its competitors. When the country is small, production will decline and foreign exchange earnings will be reduced. A large country that is a net exporter will enjoy an increase in its terms of trade, because the world price will rise. Cost increases will be passed on to the importing countries. In general, however, the introduction of environmental measures will shift resources from regulating to nonregulating countries. The flow is often from industrial countries to low-income countries, which then become the home of the world's pollutive industries and a market for restricted chemicals and drugs. In the long term, this can create problems in the nonregulating country. First, regulating countries may gain from the development of environment-friendly technologies and products. Second, when resources degrade and productivity decreases in the nonregulating country, competitiveness will ultimately decline. Whether or not such effects occur depends, of course, on the natural conditions and the environmental assimilative capacity in the nonregulating country. Third, when the regulating country obtains a leading position in the development and production of environment-friendly products or when resources degrade and productivity declines elsewhere, the regulating country may eventually regain its comparative advantage.

How strong is the impact of environmental regulation on the relocation of productive activities? Empirical studies generally show that cost differences due to differences in environmental regulations are relatively small. A number of studies show that even in the most pollution-intensive industries, pollution-abatement costs constitute only between 1 and 3 percent of total industry costs (see the studies cited in Subramanian 1992, p. 142). There is some evidence of cross-border relocation by firms in response to differences in environmental policies, but the evidence (viewed on a world scale) certainly does not suggest massive investment relocations (Dean 1992, pp. 16–20; GATT 1992, p. 31). Reduced environmental costs abroad are often counterbalanced by other considerations, such as labor availability and quality, wage rates, supporting infrastructure, tax incentives, market size, transport costs, and country risk.

Externalities of imported goods

A different issue arises when the consumption of an imported good causes pollution or affects health and safety. It is only reasonable that these goods be subjected to the same taxes or regulations as the domestic versions, because the externalities arise from the consumption of the products (rather than their production) and therefore are independent of where the products were produced (GATT 1992, pp. 31–33).[1] Import restrictions are a proper tool for enforcing domestic consumption bans or domestic standards. For example, a ban on domestic smoking would also require the prohibition of imported cigarettes, and compliance with domestic emissions standards would require a ban on cars not fitted with the appropriate catalytic converter (Subramanian 1992, p. 150).

An important distinction in this respect is the one between measures related to products and measures related to production and processing methods.[2] When environmental taxes are levied on domestic products, then similar measures can be taken against foreign imports of the same products. However, when measures are taken to influence environmentally harmful production or processing methods of domestic firms, then GATT does not allow unilateral measures to be taken against foreign products that are produced or processed in a similar, environmentally harmful, way.

An example is the well-known dispute

over imports into the United States of Mexican tuna that did not meet the U.S. dolphin protection standards. The GATT panel found that a contracting party should not be permitted to take trade measures to enforce its own laws regarding animals or natural resources outside its jurisdiction. If this were possible, then any country could ban imports merely because the exporting country pursues environmental and health policies different from its own. The panel upheld, however, the U.S. law regulating labeling of tuna products as "Dolphin Safe" (GATT 1992, pp. 26–27). The use of labeling requirements constitutes a less controversial approach to these problems, because it allows consumers the freedom to exercise their preference against eco-unfriendly processes or products (Subramanian 1992, p. 150).

The distinction between products, on the one hand, and production and processing methods, on the other, can have a negative effect on the efficiency of environmental policies (Heerink and others 1994). When a production method is environmentally harmful, then the optimal policy would influence the production process through an emissions tax or other direct instruments. A less efficient policy is to tax the product in question. For reasons of international competitiveness, however, the second option may be preferred because it implies that competitive imports can also be subjected to taxation. When measures related to production or processing methods are taken against domestic firms, then GATT rules do not allow similar protective measures to be taken against competitive foreign imports.

International environmental problems and trade measures

Use of trade measures

Trade interventions are tempting instruments for dealing with transborder or global physical spillovers. In principle, however, the choice of the appropriate intervention to correct the market failure is independent of whether the problem is domestic or international. The optimal instrument for a problem is the one among the list of feasible instruments whose base is most closely related to the source of the market failure. Thus, trade-based instruments are generally second-best instruments to correct the environmental failure relative to production- and consumption-based instruments. In very few cases is international trade in commodities the actual cause of an environmental problem (Lloyd 1992, pp. 67–69).

The difficulty with policies aimed at abating transborder or global environmental problems, however, is the absence of a supranational enforcement authority. National jurisdiction and sovereignty have to be respected. The enforcement of environmental policy stops at a nation's border. Cooperation of other countries can be secured on a voluntary basis only. Intergovernmental cooperation is essential to finding a solution. Both efficiency and equity considerations must be addressed as part of such a solution.

Efficiency issues arise when costs of abatement differ from country to country. These differences should be taken into account in order to minimize the global costs of reducing environmental damage. The contribution of each country to solving the problem should vary inversely with the costs of abatement. Equity issues arise because a country's contribution to the globally efficient cleanup effort may not match either its share of the pollution being emitted or its ability to pay. Securing multilateral cooperation will not be easy in such situations (GATT 1992, p. 34).

Mäler (1990) characterizes international negotiations on environmental problems as a game in which those who gain from cooperation must devise rules so that countries that would otherwise lose have an incentive to agree to play the game. He concludes that there will be many situations where the victim pays principle (VPP)—that is, transfers from the country whose environment has been degraded to the country that degrades the environment—will be necessary in order to achieve an efficient solution. The transfers will give the losing countries an incentive to cooperate. Adherence to the polluter pays principle (PPP) would lead to the noncooperation of these countries and the collapse of the game.

According to the GATT (1992), positive incentives are the best way to achieve sustained intergovernmental cooperation when such cooperation is not voluntarily forthcoming. Positive incentives can include offers of financial assistance and transfers of environmentally friendly technology directly related to the problem at hand or (more broadly based) offers to increase foreign aid, to lessen debt problems, and to make nondiscriminatory reductions in trade barriers. Negative incentives—in particular, the use of (unilateral) trade measures against products not related to the environmental problem at hand (as advocated, for example, by Ekins, Folke, and Costanza 1994)—are not an effective way to promote cooperation. Given the justifiable basis for a diversity of environmental standards among countries, it is important to minimize the risk of solutions being imposed by the larger or richer countries (through their greater economic or political power). Furthermore, by generating resentment and commercial frictions, negative incentives reduce the prospects for intergovernmental cooperation on future problems (GATT 1992, pp. 21, 36).

The debate over deforestation and global warming may be used to illustrate some of the issues (GATT 1992, pp. 34–35, 38). It is generally accepted that reducing carbon dioxide (CO_2) levels involves both reduced CO_2 emissions and action to slow or reverse deforestation, but opinions differ as to which approach to emphasize. One way of viewing the situation is that growing forests provide carbon absorption services to a world that is dumping increasing amounts of carbon into the atmosphere. Since countries that have a high ratio of (growing) forests to domestic carbon emissions are not paid for exporting carbon absorption services to the rest of the world, they have little incentive to take such services into account when deciding how to use their forests. The result is most likely a faster rate of deforestation than would otherwise occur. Rather than being threatened with restrictions on their exports, it seems logical that these countries should be offered compensation for exporting carbon absorption (and biodiversity) services.

Resource transfers themselves will affect global environmental quality, because income levels and environmental quality are highly correlated. For example, resource transfers to low-income countries may reduce poverty-induced environmental degradation in these countries (Subramanian 1992, p. 148).

Although trade measures should generally not be used to correct market failures that create environmental problems, multilateral trade measures can play a role in the promotion and enforcement of international cooperation on environmental issues (see Blackhurst and Subramanian 1992; GATT 1992; Subramanian 1992; Verbruggen 1991). Multilateral trade provisions (applicable to products directly related to the environmental problem) may be used to enforce and sustain multilateral agreements. Their primary purpose is to prevent the agreement from being undermined by trade between nonparticipants and participants. Trade provisions are generally such that nonparticipants are at a disadvantage. They therefore create a positive incentive to join the agreement (Blackhurst and Subramanian 1992).

Impact on trade

What will be the impact of multilateral environmental agreements on international trade flows? It is difficult to draw general conclusions, because the resulting changes in trade flows clearly depend on the precise contents of the agreement in question and its implementation. When a tax is introduced on a specific environmentally damaging commodity, the profits made by producers of the good will decrease, the price paid by users will rise (depending on the prevailing market conditions), or both. The volume of international trade in the environmentally damaging good will generally decline. Studies on the introduction of carbon taxes by Whalley (1991) and Whalley and Wigle (1991), using a global general equilibrium model, indicate that interregional gains and losses are highly dependent on the type of tax implemented but are not insignificant in size. When a global tax is introduced on the production of greenhouse energy products, and the tax revenues are distributed proportionally to population size, then the oil exporting region will suffer a terms of trade loss, while nonoil exporting developing countries will experience an overall gain (Whalley and Wigle 1991). Other potential elements of multilateral agreements can have either a direct (trade sanctions or trade provisions) or indirect (side payments to compensate losing countries) impact on the pattern of international trade in products related and not related to the problem at hand. Quantitative models that describe the relationships between the most important components of a multilateral agreement and international trade in related and unrelated commodities are needed to assess the resulting impacts.

Trade liberalization and the environment: Theoretical considerations

The potential impact of trade liberalization on environmental degradation has been hotly debated in recent years. On the one hand, environmentalists often claim that if production or consumption of a good has negative environmental effects, then the expansion of world output of that good following trade liberalization will lead to greater environmental degradation (assuming no changes in environmental policies or production methods). In addition, the increase in trade flows will intensify transport-related externalities. On the other hand, others (predominantly economists) have claimed that trade liberalization will often benefit the environment. For example, the GATT (1992) argues that there is no reason to assume that growth of per capita income (boosted by expanding trade) necessarily, or even on average, damages the environment, because increases in per capita income provide more resources to contain environmental damage and make people better aware of the need to devote resources to the environment. Moreover, the better trade opportunities facilitate the implementation of environment-improving processes, and trade in recycled inputs can help countries to economize on resource use (GATT 1992, pp. 19–20). Other proponents of trade liberalization argue that liberalization increases production efficiency and reduces pressure on resources, because countries tend to specialize in those goods that use relatively abundant factors of production (Heckscher-Ohlin model), and that increases in income alleviate poverty-related environmental pressures and induce a transition to sustainable production methods.

When environmental policies of trading partners are such that environmental externalities are corrected in an appropriate way, trade liberalization will increase national and global welfare (provided a number of standard assumptions on the functioning of markets are satisfied). However, despite their desirability from a welfare-economic point of view, first-best environmental policies may not be adopted for political or other reasons. Instead, governments often rely on second-best or third-best policies or do not address certain environmental problems at all. The discussion on the environmental impact of trade liberalization mainly focuses on situations where appropriate environmental policies are lacking.[3] No simple, unequivocal answer can be given with regard to the impact of trade liberalization in such situations. Besides the arguments mentioned above, an analysis of this question should also take into account the effect of increases in income on technology and commodity mix. The increase in income and change in relative price that result from trade liberalization are likely to induce changes in production technologies. In the absence of appropriate environmental policies, the environmental effects of such changes in technology can be positive or negative. In addition, increases in income resulting from trade liberalization will change the composition of consumption and production. Externalities related to consumption and production differ greatly from commodity to commodity. The resulting environmental impact of income increases is therefore difficult to assess.

According to Runge (1993), five separate effects of trade growth on the environment may be distinguished, namely the effects on (1) allocative efficiency, (2) scale of economic activity, (3) output composition, (4) technology, and (5) environmental policy. The overall effect of trade on the environment is the sum of these separate impacts, which may be positive or negative, depending on the case examined.

The theory of comparative advantage stipulates that trade promotes allocative efficiency by inducing patterns of production that are less wasteful than they would be if every country tried to produce a full range of goods and services itself. In this sense, more open trade leads to higher levels of economic satisfaction than inward-looking policies closed to trade and also reduces waste of scarce resources. This means that, for a given endowment of resources, trade will be less wasteful than autarchy, the absence of trade (Runge 1993, p. 18). However, the exercise of comparative advantage and more open trade is itself not inconsistent with overexploitation of globally scarce resources. For example, when a country is endowed with a resource that is locally abundant but globally scarce, then this resource could better be conserved than traded (Runge 1993, p. 19).

Besides changing the international pattern of production, trade growth also increases the total scale of economic activity. This raises the question of whether environmental damage increases in proportions the same as or similar to the scale of activity. Empirical analyses of changes over time in different countries indicate that pollution increases at a decreasing rate with gross domestic product (GDP) per capita up to a certain threshold. After the threshold (which is at about $5,000 for sodium dioxide), the level of pollution decreases (Grossman and Krueger 1993; World Bank 1992, p. 40). According to Runge (1993), this nonlinear relationship between scale of economic activity and pollution indicates that other forces are at work, influencing how growth due in part to trade affects the level of environmental quality. These forces include the composition of output, technology, and policy decisions.

The composition of output plays an important role when increases in GDP lead to shifts in production from industrial sectors with high levels of pollution to services with lower levels of pollution. This change in the composition of output reduces total pollution levels, offsetting some of the scale effects of economic growth through trade (Runge 1993, p. 23).

A fourth way in which trade may affect the environment is through changes in technology. As higher value is given to environmental quality with increases in income, markets for green technologies may develop and grow. The development of new environmental technologies may be accompanied by changes in traditional technologies that lower the overall level of residuals and hazards from manufacturing processes (Runge 1993, pp. 23–24).

Finally, growth in GDP per capita may lead to an increasing demand for environmental policy. According to Runge, the negative scale effects of economic growth on the environment are offset by output composition and induced technological changes to a degree largely determined by the government's regulatory framework. Schematically, we can think of trade as inducing allocative efficiency, which in turn leads to economic growth with the attendant negative scale effects. These scale effects may lead to increases in the demand for environmental protection and policies to accomplish this protection, inducing changes in output composition and production technologies, which in turn diminish negative externalities (Runge 1993, pp. 24–25).

The analysis by Runge (1993) does not explicitly account for changes in transport flows that result from trade growth. The environmental effects of increased international transportation can be considerable. First, the construction of additional infrastructure (roads, railways, harbors, storage facilities) generally affects the natural scenery in a negative sense. Second, energy use in international transport makes a substantial contribution to carbon dioxide emissions and other air pollution. Energy prices are relatively low in international transport, because advantage can be taken of differences between countries in energy tax rates. As a result, international transport flows are probably much larger than they would be if transport prices reflect the full environmental costs of transportation.

For an examination of the effects of trade liberalization on the environment, it is important to extend the foregoing analysis by including the effects of changes in the prevailing structure of trade impediments. The two most relevant features are the antiprocessing tendencies of tariffs and the high barriers against labor-intensive imports from developing countries. In recent decades, comparative advantage has shifted toward the developing countries for a range of labor-intensive products and resource-based manufactures that were once produced more efficiently in the industrial countries. In order to protect their declining industries, industrial countries typically set their tariffs much higher on processed products than on raw materials (see, for example, Balassa 1968; Yeats 1977). Besides, nontariff barriers such as "voluntary" export restrictions or regulations affecting quality standards and health and sanitary requirements are increasingly used to protect domestic manufacturers from foreign competition. As a consequence, most processing industries are located in high-income countries. Reduction of tariff barriers is likely to induce processing industries to relocate in countries that are rich in natural resources and to change considerably the pattern of trade (for example, transport flows) in processed and unprocessed products.

Import restrictions on labor-intensive goods from developing countries have important environmental effects as well. Because developing countries have a comparative advantage in labor and in natural resources, a reduction of barriers against labor-intensive imports implies a shift from the production of resource-intensive goods to the production of labor-intensive goods in developing countries. A decrease of natural resource depletion is likely to be the result.

Environmental effects of agricultural trade liberalization

As argued in the previous section, the overall effect of trade on the environment can be positive or negative, depending on the case examined. Empirical models can serve as a useful tool for assessing the overall impact of the various direct and indirect effects of trade liberalization on environmental degradation. Empirical estimation of the different counteracting effects is needed to appraise the direction and magnitude of the relationship (see also Lutz 1992).

As far as agriculture is concerned, available models of trade in agricultural products are not capable at present of analyzing the environmental effects of trade liberalization, because environmental variables are lacking in these models.[4] However, some recent studies have used the simulation results of these models as a benchmark for assessing potential environmental effects in a qualitative sense (see Anderson 1992a, 1992b; Lutz 1992).

Anderson (1992a, 1992b) uses the GLS model to examine the effects of trade liberalization for three ecologically sensitive products, such as grains, ruminant meat, and sugar. Results of a reference scenario for 1990 are compared with the results of a liberalization scenario in which all food price distortions in industrial and developing economies have been removed and full adjustment has been accomplished within that same year.[5] An important feature of the model is the assumption of induced technological change in the sense that growth in farm productivity responds positively to changes in the product price. The model is a partial equilibrium model, implying that the focus is on efficiency gains within agriculture. It cannot be used to analyze income and expenditure effects, indirect efficiency effects, and relative price changes throughout the economy.

The simulation results indicate that the total world food production hardly changes as a result of trade liberalization but that the regional distribution of food production changes considerably. Production declines the most in Western Europe and Japan. Food production in North America and East Asia (except China) declines as well. Production of all three commodities increases in China, Latin America, and Sub-Saharan Africa.

On the basis of this outcome, Anderson argues that the international relocation of cropping production reduces substantially the use of chemicals in world food production, because food production shifts from countries with relatively high producer prices to countries with low producer prices. Increased chemical use in countries with relatively low producer prices is more than offset by lower applications of chemicals that result from production declines in high-priced countries. The underlying reason is that empirical data suggest an exponential relationship between the price of farm output and the use of farm chemicals per unit of output (Anderson 1992a, pp. 162–63). The global reduction in chemical use occurs all the more so because most of the countries where production expansions are concentrated tend to be relatively sparsely populated;[6] the consequent lower price of land in these countries is assumed to result in fewer farm chemicals per unit of output than in relatively densely populated countries at identical prices of farm output (Anderson 1992a, pp. 163–64).

The relocation of meat and milk production from intensive grain-feeding enterprises in densely populated rich countries to pasture-based enterprises in relatively sparsely populated poorer countries is another factor associated with lower use of chemicals such as growth hormones and medicines for animals. The greater use of these less intensive production methods reduces not only air, soil, and water contamination generated by farmers but also the average chemical intake by the world's food consumers. Food consumers in densely populated Western Europe and Japan, where price and trade policies and high land prices currently encourage the heaviest use of farm chemicals and the most intensive methods of feeding, would have the most to gain from the effect of such reforms (Anderson 1992a, p. 164).

Anderson also considers environmental externalities related to primary factors of production. Although primary production factors are much less responsive to price changes than variable inputs are, they do respond over the longer term. A slowdown in the flow of labor to urban areas as a result of higher agricultural prices would reduce urban environmental problems, especially in developing countries where that labor is employed in smokestack industries. Land clearance for agricultural purposes may contribute to deforestation. Available empirical evidence cited by Anderson (1992a,

p. 166) indicates, however, that land area is by far the least responsive factor to changes in farm output prices. Moreover, the negative impact of price liberalization is likely to be small compared with the negative impact of inadequate enforcement of forest property rights and of tax incentives and subsidy policies that encourage felling to promote agricultural and mineral development projects. And, in any case, the negative impact of trade liberalization has to be weighed against the reforestation on former farmland in industrial countries that liberalize agricultural trade and the environmental effects of forgone production in developing countries where resources would otherwise have been employed (Anderson 1992a, pp. 164–67).

According to Lutz (1992), the responsiveness of production factors in developing countries to agricultural price changes depends on farm size. The response of large farms is very significant, while the response of small farms is comparatively small and inelastic for all factors of production. In developing countries with a commercial farm sector, increased agricultural prices will therefore result in more intensive use of resources and associated negative environmental effects of that subsector. Increased absorption of farm labor by the commercial sector could potentially have some offsetting positive effects if the labor otherwise would be farming marginal areas and extending the frontier, but the impact is unlikely to be large.

Negative environmental effects in developing countries could also partially be offset via the income effect of higher prices. Higher incomes permit farmers to use production techniques that are more environmentally benign and to make some additional conservation-type investments that increase long-term productivity. In the view of Lutz, these potentially positive effects are expected to be small, but empirical work should be undertaken to determine what they are.

In his conclusion, Lutz holds that higher world agricultural prices lead to economic benefits for developing countries, but the associated environmental effects are expected to be negative; however, because of positive offsetting effects, this cannot be concluded unambiguously without empirical examination.[7] He stresses Anderson's (1992a, 1992b) point that a removal of distortions on farm prices could and should be accompanied by the introduction of more optimal environmental policy instruments, including the removal of any farm input subsidies or policies to discourage deforestation. As a general proposition, not only should trade liberalization never be canceled for environmental reasons, but its benefits could be enhanced if appropriate environmental measures were taken at the time of liberalization (Anderson 1992a, p. 168).

A number of comments on the outcome of these studies can be made.[8] First, these studies make no distinction between environmental effects for different groups of developing countries. In Sub-Saharan Africa and other regions where the green revolution has not had much impact thus far, use of chemical inputs is at very low levels. Taking into account the low estimates of (long-term) supply response found in empirical studies for Sub-Saharan Africa and other low-income countries (see, for example, Chhibber 1989), higher farm output prices are unlikely to cause significant problems due to intensive use of these inputs within one or two decades (or even longer). On the contrary, because farmers are mining their soils in large parts of Africa, increased use of chemical fertilizer may in fact contribute to restoring the nutrient balance in these countries.

Second, higher international prices may induce farmers in developing countries to shift from food crops toward export crops. Such a shift may have important but complicated environmental consequences, because the amount of environmental damage varies markedly by type of crop. For example, increased export production enhances soil nutrient depletion (because export production disrupts the natural cycle of soil replenishment), but in the case of perennials the continuous soil cover provides obvious ecological advantages compared to annual food crops. In the United States, erosiveness is relatively high for cotton and soybeans and relatively low for wheat and rice. Fertilizer and pesticide requirements also differ considerably from crop to crop (Reichelderfer 1990, table 1).

Third, increased trade aggravates transport-related environmental externalities. Environmental effects of transport may be relatively high for a number of agricultural and food products. Transportation of bulky, unprocessed agricultural products is relatively energy intensive and hence costly in financial as well as environmental terms. Moreover, the perishable nature of many agricultural products requires that fast but energy intensive means of transport be used. Examples are the transportation of kiwis, eggs, and flowers by airplane. As discussed in the previous section, energy prices in international transport are relatively low and do not reflect the environmental damage involved.

Price changes and soil degradation

The discussion in the previous section indicates that the analysis of environmental effects of agricultural trade liberalization is still in its infancy and is susceptible to further improvements (see also Anderson and Strutt 1994). One important element that deserves more attention is the possible impact of price changes resulting from trade liberalization on soil degradation in developing countries. The deterioration and loss of arable land probably is the most threatening environmental problem in developing countries at the moment. Large areas of land are facing reduced productivity or are no longer used for agricultural purposes as a result of erosion, nutrient depletion, or salinization. Food availability and accessibility for large population groups may be severely reduced in the near future if these trends continue.

Types of soil degradation

Several types of soil degradation can be distinguished. The importance of each type differs greatly from region to region. The main aspects of soil degradation are erosion, nutrient depletion, salinization and waterlogging, and compaction.

Erosion. Erosion is a key component of soil degradation, characterized by irreversibility and off-site effects. Although erosion is a problem for temperate soils as well (for example in the United States), its impact on aggregate agricultural production is much larger in tropical countries. Soils, rainfall, and agricultural practices in tropical countries are more conducive to erosion. For countries such as Costa Rica, Malawi, Mali, and Mexico, estimates of economic losses due to gross soil loss range from 0.5 to 1.5 percent of GDP annually (World Bank 1992, pp. 55–56).

Erosion can have important positive or negative off-site effects, depending on where the eroded soil ends up. On the one hand, it may harm productivity by depositing silt in dams, irrigation systems, and rivers and by damaging fisheries. On the other hand, eroded soil may add to agricultural land elsewhere. As such, it represents a geographical shift in agricultural productivity.

Nutrient depletion. A related problem is that of nutrient depletion. Maintenance of soil fertility requires a balance between nutrient losses (through uptake by crops, livestock raising, erosion, leaching, and so on) and nutrient replacements (through manure, chemical fertilizer, crop residues, and so on). If over a period the balance is negative, nutrients are being mined from the soil. As a result, agricultural production takes place at the expense of future generations. When losses exceed nutrient gains, application of chemical fertilizer can help to restore the balance.[9]

Soil nutrient depletion is a major problem in large parts of Sub-Saharan Africa (see, for example, Stoorvogel and Smaling 1990). African farmers have exhausted their soils for a long time. Traditionally, lack of fertilization was compensated by long fallow periods. Increasing pressure on land due to population growth and increases in farm size has eliminated the recovery period or considerably reduced its length. Soil depletion is the inevitable outcome of this process (Van der Pol 1992). In addition, population pressures increase the demand for firewood. The resulting removal of tree cover has important effects on the nitrogen contents of the soil (and on soil erosion by wind and water). As more and more people turn to dung and straw for cooking, the natural cycle of soil replenishment is further disrupted (Pomfret 1992, p. 205).

Salinization and waterlogging. Salinization and waterlogging have become growing problems in certain irrigated areas in recent years. Irrigated land is deteriorating in many countries, partly as a result of bad management practices. According to Repetto, more than 20 million of hectares in India and Pakistan have been lost through waterlogging, and at least 30 million are seriously affected by salinization (Repetto 1989, p. 76). Salinization is not just a problem of irrigated land. Most of it occurs naturally. Globally, nearly one-third of arable land is affected by elevated salt concentrations (World Bank 1992, p. 57).

Compaction. Compaction is usually caused by the use of heavy machinery on soils with a relatively unstable structure. It has become a serious problem in certain regions, particularly in Africa and Europe. More information on soil degradation is given in the appendixes. Appendix 7-1 gives an overview of the various types of soil degradation and their definitions, while appendix 7-2 provides quantitative information on the magnitude of different types of soil degradation on a global and regional scale.

Causes

Soil degradation in developing countries is affected by many factors. Perhaps the most important one is the quality of the land resource. Poor soils are much more sensitive to erosion, nutrient depletion, and other degradation processes than relatively rich soils. The better the quality of the land, the more likely farmers are to invest in conservation measures. The system of land rights also plays a crucial role in soil conservation decisions. Security of property rights is an important precondition for soil conservation investments by farmers. Another key element is farmers' awareness of soil mining. Information and extension services can play a crucial role in this respect.

At the macro level, population growth and policy, environmental policy, and agricultural pricing policy are important factors. Population growth may lead to increased cultivation of marginal soils or to shorter fallow periods (such as a reduction in the recovery period of the soil). However, it also will generally increase land prices and hence stimulate soil conservation investments. Prevailing environmental policies are another major factor. Measures to promote soil conservation practices are an important element of environmental policies in some developing countries. But, as discussed above, there exist large differences between countries in the importance attached to sustainability issues and in the type of environmental policy and its actual implementation. Finally, agricultural output and input prices (particularly the fertilizer price) affect crop choice, input use, and production levels, which in their turn determine erosion, nutrient depletion, and other soil degradation processes.

What will be the effect of agricultural trade liberalization on soil degradation in developing countries? Studies on the effects of trade liberalization in agricultural products by OECD (Organization for Economic Cooperation and Development) countries indicate that world market prices of agricultural products will rise, particularly the prices of the most protected crops. Depending on whether or not developing countries also liberalize their policies, world market prices of tropical crops like cocoa or coffee may decline (Brandao and Martin 1993). The resulting effect on domestic agricultural prices depends on the extent to which world market prices are transmitted to domestic prices. Agriculture in most countries is subject to considerable intervention, which creates a gap between world prices and domestic prices and which generates cross-country variation in prices. An empirical analysis by Mundlak and Larson (1992) of the relationship between world prices and domestic prices for fifty-eight countries and sixty agricultural products indicates, however, that most of the changes in world prices are transmitted to domestic prices and that world prices are the major contributor to variations in domestic prices.

Changes in agricultural prices

The question as to whether the higher (lower) agricultural prices will lead to increased soil degradation in developing countries has resulted in different views. Repetto (1989) claims that a higher price for agricultural output will affect soil conservation positively. Raised agricultural profitability increases the derived demand for farmland, labor, and other inputs. Because land cannot massively be shifted into other uses, rising output prices will increase the value of farmland, and the returns on farmers' investments in the development and conservation of farmland will increase. Thus farmers are encouraged to level, terrace, drain, irrigate, or otherwise improve their land.

Lipton (1987), however, argues that a high price will have negative effects on soil conservation because it will promote quick depletion of the soil: better farm prices now will encourage soil mining for quick, big crops now.

Other authors take intermediate positions. Barrett (1991) argues that price changes will not have much effect on soil conservation, because price increases raise instant benefits of overcultivation now but future benefits when the soil is conserved as well. According to Barrett, these two effects are more or less equal; thus for the farmer the output prices are not important for his or her decision. For the farmer it only matters whether erosion or conservation will increase farm profits (over a longer term).

As mentioned in the previous section, Lutz (1992) postulates that the negative environmental effects of more intensive resource use may partially be offset by the income effect of higher prices. The higher income will permit farmers to use production techniques that are more environmentally benign. Conceivably, because the higher income will result in a slightly lower discount rate, farmers will make additional conservation investments that increase the long-term productivity. However, these potentially positive effects may be small.

Part of the controversy in ideas about whether higher prices will lead to increased soil degradation can be explained by the fact that different aspects of the relationship between soil degradation and price changes are addressed. In order to analyze the effects of trade liberalization on soil degradation, it may be useful to distinguish four elements that will be affected by price changes: current versus future production decision, farm practices, productivity versus conservation investments, and farmer private discount rate.

Current versus future production decision. Higher output prices may induce farmers to increase their production at the expense of soil quality (through erosion, nutrient depletion, and so forth) or to cultivate marginal lands that are more susceptible to erosion. As a result, future productivity of the land declines (overcultivation). Conservation of soil nearly always requires sacrifices in output in the short run. A farmer has two choices: either to cultivate more and gain immediately at the expense of the soil and hence of diminished future gains or to produce less and benefit in the future at the expense of short-term output. Important determinants of farmers' decisions in this respect are input and output prices, private discount rates, and land tenure arrangements.

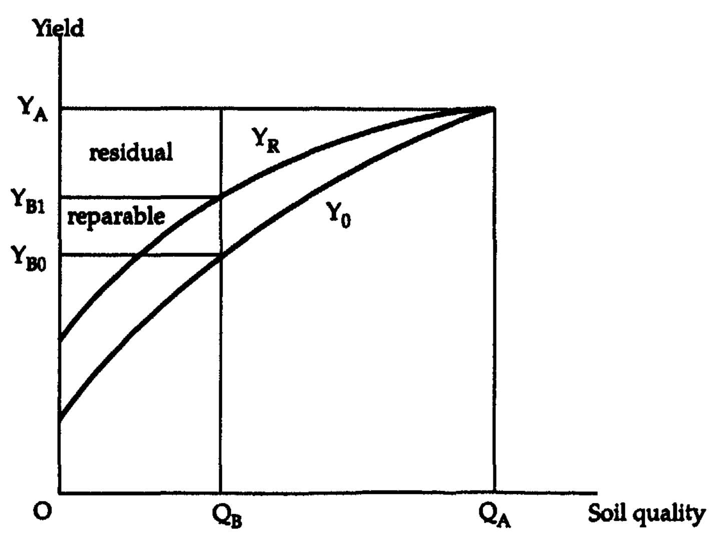
Farm practices. Part of the yield damage caused by agronomic practices that degrade the soil can be recovered by changing farm practices, input use, or both. Van Kooten (1993) calls this "reparable soil damage." For example, as long as there is adequate topsoil, losses in organic matter can be overcome by one or two years of "green manure."

In figure 7-1, Y_0 represent the yield function and Y_R the restored yield curve. When soil quality declines from Q_A to Q_B, yields decline from Y_A to Y_{B0}, which represents the total yield damage due to soil degradation, given that farm practices or input use do not change in response to the decline in soil quality. An amount $Y_{B1} - Y_{B0}$ of the lost yield can be recovered by changing farming practices or input use. This is the reparable yield damage and is equivalent to the "revolving fund" component of the soil. This leaves the amount $Y_A - Y_{B1}$ that represents the residual yield damage and is equivalent to the "conservable flow" component of the soil (if it is worthwhile to prevent soil degradation) or the "expendable surplus" component (if it is not worthwhile to prevent degradation).

Productivity versus conservation investments. The higher incomes that result from price increases permit farmers to undertake productivity investments (animal traction, irrigation) and conservation investments (terraces, bunds, windbreaks). Moreover, increased profitability means that demand for farmland, labor, and other inputs will increase. Since land cannot massively be shifted into other uses, rising output prices will increase the value of farmland and the returns on farmers' investments in the development and conservation of farmland (Repetto 1989).

Both productivity and conservation investments require household expenditures on variable inputs (labor and nonlabor),

Figure 7-1. Residual and reparable soil damage



Source: Van Kooten 1993.

investments in capital (human and physical), and own liquidity and therefore may compete with each other for these factors. There are some important differences between these two investment types as well: households may perceive greater risk and uncertainty of net benefits in conservation investment; the short-term benefits may be less observable to the farmer than is the case for productivity investments; externalities associated with conservation investments produce spillovers and free-rider problems that may reduce incentives to make these investments; many conservation investments require substantial expenditures of labor or cash or both; and potential credit constraints are higher for conservation investments (Reardon and Vosti 1992).

Security of property rights is an important precondition for farm households to consider long-term investments in land improvement. When property rights are ill-defined, higher prices will hardly affect household investments in conservation projects but will probably result in excessive exploitation and cultivation of marginal lands.

Farmer private discount rate. When agricultural output prices rise, the discount rate may change as a result. Just like other deprived groups, poor farmers are likely to have high discount rates because they need to satisfy basic needs without delay. So, when farmers' incomes rise (as a result of higher prices and increased production), the discount rate is likely to decrease. This means that future production will be valued relatively higher. However, farmers who produce for the export market rarely are among the very poor because they have access to land and to product markets. Again, the ownership of land plays an important role. When land property rights are not secured, farmers are not likely to invest in soil conservation even when the discount rate declines.

Changes in relative prices of tradables

Changes in world market prices due to trade liberalization have a direct effect only on the domestic prices of traded crops (to the extent that world market prices are transmitted), which means that relative prices between traded and nontraded crops within countries will change. Farmers may respond by adjusting their crop mix when relative prices change. The strength of the response depends on the available marketing infrastructure, particularly on transport facilities and information services. A shift toward tradable crops may have important consequences for soil quality, because different crops have different effects on soil degradation. Tree crops like coffee, cocoa, rubber, or bananas provide a continuous root structure and canopy cover and are suitable for sloping terrain. Other commercial crops, such as cotton or groundnuts, and staple food crops, like cassava or millet, leave the soil more susceptible to erosion. The effect of changing relative prices on soil degradation therefore depends on the resulting change in crop mix. However, cropping patterns are determined to a large extent by resource quality and comparative advantages of agro-ecological zones. Furthermore, land use technologies for a given crop may change as a result of price changes. The associated changes in fertilizer use or treatment of crop residues clearly affect soil nutrient content.

Commercial crops are usually grown in monoculture. In general, monoculture has a negative effect on the soil. Pesticides used to annihilate the plagues that emerge quickly in monocultures kill useful organisms that contribute to a good physical and organic soil structure as well. In addition, monoculture often results in a low vegetation cover, which enhances erosion.

At the macro level, a shift toward export crop production means that nutrients subtracted from the soil are exported out of the country and hence are removed from the ecological system. When no extra fertilization is applied to compensate for these losses, soil nutrient depletion is the result.

Finally, agricultural trade liberalization not only will result in higher prices for most traded crops but also is expected to lead to more stable prices. Farmers' decisions with regard to soil conservation will be affected, since more stable prices tend to lower the private discount rate of farmers. This means that future production will be valued relatively higher, and conservation investments will be likely to increase.

The foregoing analysis indicates that much more empirical work on the effects of price changes on soil degradation under different local circumstances (soil, climate, income levels, property rights system, and so forth) is needed before we will be able to assess the effects of price changes resulting from agricultural trade liberalization on soil degradation in developing countries (see also Barrett 1991; Lutz 1992). Available models of overcultivation, conservation investments, and changing farming practices, such as the ones developed by McConnell (1983), Barbier (1990), Barrett (1991), and Miranda (1992), provide a useful starting point. For analyzing the effects of price changes, a comprehensive farm-level model that includes off-farm activities, income, and consumption as well is needed. In addition, the private discount rate should be an endogenous variable in such a model. Empirical estimation of the resulting model will make it possible to assess the relative strength of the various counteracting mechanisms and to obtain estimates of the resulting effect of price changes on soil degradation under different circumstances.

Conclusions

This chapter discusses some of the major policy issues in the field of international trade and the environment, using the current state of the theory on environment and trade. Introduction of environmental policies raises a number of questions regarding a country's competitiveness, international harmonization of environmental standards and measures, and the potential role of trade measures. For analytical purposes, domestic or local environmental effects are distinguished from international (transborder) and global environmental effects. Because no supranational enforcement authority exists, international policies should be based on international agreements between sovereign states.

As regards national environmental problems, international harmonization of environmental standards is generally not desirable. Differences in national priorities and in capacities to cope with environmental and natural resource degradation justify variations in environmental standards across countries. Hence, countries should not protect their industries against imports from countries with lower standards. Nevertheless, harmonization of the form of environmental policy (principles and measures) is highly desirable. Tensions between trade and the environment may be reduced by global adherence to the polluter pays principle.

The cost-effectiveness of measures to address international or global environmental problems may differ between countries. For tackling these problems, positive incentives (such as financial assistance and transfers of environment-friendly technology) may be needed to achieve cooperation of countries for which additional benefits are low. Adherence to the PPP will generally lead to the noncooperation of these countries. Negative incentives (such as discriminatory trade restrictions on unrelated products) may not be the best way to promote cooperation.

The effect of the growth in international trade on the environment can be positive or negative, depending on the case examined. Six separate effects are distinguished, namely the effects on (1) allocative efficiency, (2) scale of economic activity, (3) transport flows, (4) output composition, (5) technology, and (6) environmental policy. The second and third factors have a negative effect on environmental quality, whereas the other effects are generally positive. Empirical estimation of the different counteracting effects is needed to appraise the direction and magnitude of the relationship between trade growth and the environment. For an analysis of the environmental effects of trade liberalization, it is important to take into account the prevalent structure of trade impediments (particularly the antiprocessing tendencies of tariffs and the high barriers against labor-intensive imports from developing countries) as well. Removing these structural distortions will have important environmental effects, particularly on the depletion of natural resources.

Studies of the environmental effects of a worldwide removal of food price distortions indicate that resource use in agriculture will increase in developing countries with a commercial farm sector. In addition, land clearance is likely to contribute to deforestation in these countries. On a global scale, the increased use of chemicals in developing countries will, however, be more than offset by lower applications of chemicals that result from production declines in high-priced countries. The total level of air, soil, and water contamination by farmers and the average chemical intake by the world's food consumers will decline as a result.

Production estimates derived by simulation models of world food markets are used for assessing these environmental effects. Obviously, such qualitative inferences are rather crude and leave much room for extension and refinement. One apparent extension would be the incorporation of transport flows and transport-related environmental externalities. But probably even more important is to include a more comprehensive analysis of the effect of trade liberalization on soil degradation, the most threatening domestic environmental problem in many developing countries at the moment. In particular, the potential role of increased fertilizer use (and fertilizer subsidies) in preventing soil nutrient depletion in low-input agriculture needs much more attention.

Whether or not higher agricultural prices resulting from trade liberalization will lead to increased soil degradation is a question in dispute in the literature. This chapter argues that the controversy can be explained by the fact that different studies address different aspects of the relationship. At least four elements should be distinguished, namely the effect of price changes on (1) decisions between current and future production, (2) changes in farm practices and input use, (3) decisions between production and conservation investments, and (4) farmers' private discount rates. Empirically estimated models at the farm level are needed to assess the resulting impact of price changes on soil degradation under different local circumstances. An important use of the resulting models is the assessment of circumstances under which the effect of trade liberalization on soil conservation will be positive (or negative).

Appendix 7-1. Definitions and types of soil degradation

Soil degradation can be defined as the deterioration or total loss of the short-term or long-term productive capacity of the soil, the aggravation of soil pollution, and changes affecting the state and role of soil within ecosystems. *Soil conservation* is defined by Van Kooten (1993) as maintenance of the stock of resources and the present level of productivity of the soil for future generations, assuming a given state of the art. This does not mean nonuse, but rather the redistribution of use rates in the direction of the future.

Soil conservation is necessary to avoid degradation of land. The problem of land degradation is a worldwide problem. It refers to soil erosion, chemical deterioration, and physical deterioration:

- *Soil erosion* involves the displacement of soil material. The two major types of soil degradation in this category are *water erosion* and *wind erosion.* Soil erosion occurs in almost every country. It causes loss of topsoil and soil deformation and may have important off-site effects such as overblowing. *Loss of topsoil* is defined as the uniform displacement of topsoil by water or wind action. *Soil deformation* refers to the uneven displacement of soil material by water or wind action. It leads to rill and gully formation, deflation hollows, and dunes. *Overblowing* is defined as the coverage of the land surface by wind-carried particles. It may influence structures like roads, waterways, and buildings, but it can also cause damage to the land.
- *Chemical deterioration* refers to internal soil chemical deterioration processes. In this category, only on-site effects are recognized on soils that have been abandoned or forced into less intensive usages. Chemical deterioration includes loss of nutrients or organic matter, salinization, pollution, and acidification. *Loss of nutrients (organic matter)* is the process that takes place when fields under cultivation give up more nutrients (organic matter) than they gain. It occurs if agriculture is practiced on poor or moderately fertile soils, without sufficient application of manure or fertilizer. Loss of nutrients is a widespread phenomenon in countries where low-input agriculture is practiced. *Salinization* is caused in particular by poor management of irrigation schemes or by the intrusion of saline (sea) water into groundwater reserves. *Acidification* may occur on drainage of pyrite-containing soils or by excessive application of acidifying fertilizer. *Pollution* is caused by industrial waste accumulation but also by excessive use of pesticides, excessive manuring, and so on.
- *Physical deterioration* refers to internal soil physical deterioration processes. It includes compaction, sealing and crusting, waterlogging, and subsidence of organic soils. Like chemical deterioration, it has on-site soil effects. *Compaction* is usually caused by the use of heavy machinery on soils with a relatively unstable structure. *Sealing and crusting* of the topsoil occur when the topsoil does not provide sufficient protection from the impact of raindrops. *Waterlogging* includes flooding by river water and submergence by rainwater caused by human intervention in natural drainage systems. *Subsidence of organic soils* may be caused by drainage or oxidation. Physical deterioration gene-rally is a relatively small problem.

In nature, processes of soil degradation do not necessarily operate strictly separately from one another. For example, compaction and crusting decrease water infiltration, causing higher runoff of rainwater and increasing water erosion. Erosion of fertile topsoil can be caused by loss of nutrients due to changes in the physical structure of the soil and the vegetation. Moreover, loss of nutrients by the erosion of fertile topsoil is an important side effect of erosion.

Quantitative information on the areal extent of the different types of soil degradation listed above is provided in appendix 7-2.

Appendix 7-2. Magnitude of human-induced soil degradation

In recent years, a world map on the status of human-induced soil degradation has been prepared on the basis of information provided by a large number of soil scientists throughout the world (Oldeman, Hakkeling, and Sombroek 1991). These scientists were asked to give their expert opinions on soil degradation in their particular geographic region. The map primarily indicates human-induced soil degradation. Natural degradation processes that lead to extreme conditions such as deserts, salt flats, arid mountain regions, or ice caps were distinguished as a separate category (wasteland). Areas not affected by human intervention at all (because of very low population densities) were categorized as stable terrain.

Using the data base of the Global Assessment of Soil Degradation (GLASOD) map, Oldeman, van Engelen, and Pulles (1991) have provided quantitative information on the areal extent of different types of soil degradation. Figure 7-2, which gives an overview of the magnitude of different types of soil degradation on the earth's surface, is based on that information. The estimates presented refer to the years 1987–90. Because no systematic evaluation of the status of human-induced soil degradation has been made, it is not possible to indicate the rate of human-induced soil degradation.

As can be seen from the figure, 40 percent of the total land surface is not affected by human activities (wasteland and stable land). Of the remaining 60 percent, 45 percent is nondegraded, while 15 percent suffers to various degrees from human-induced degradation.

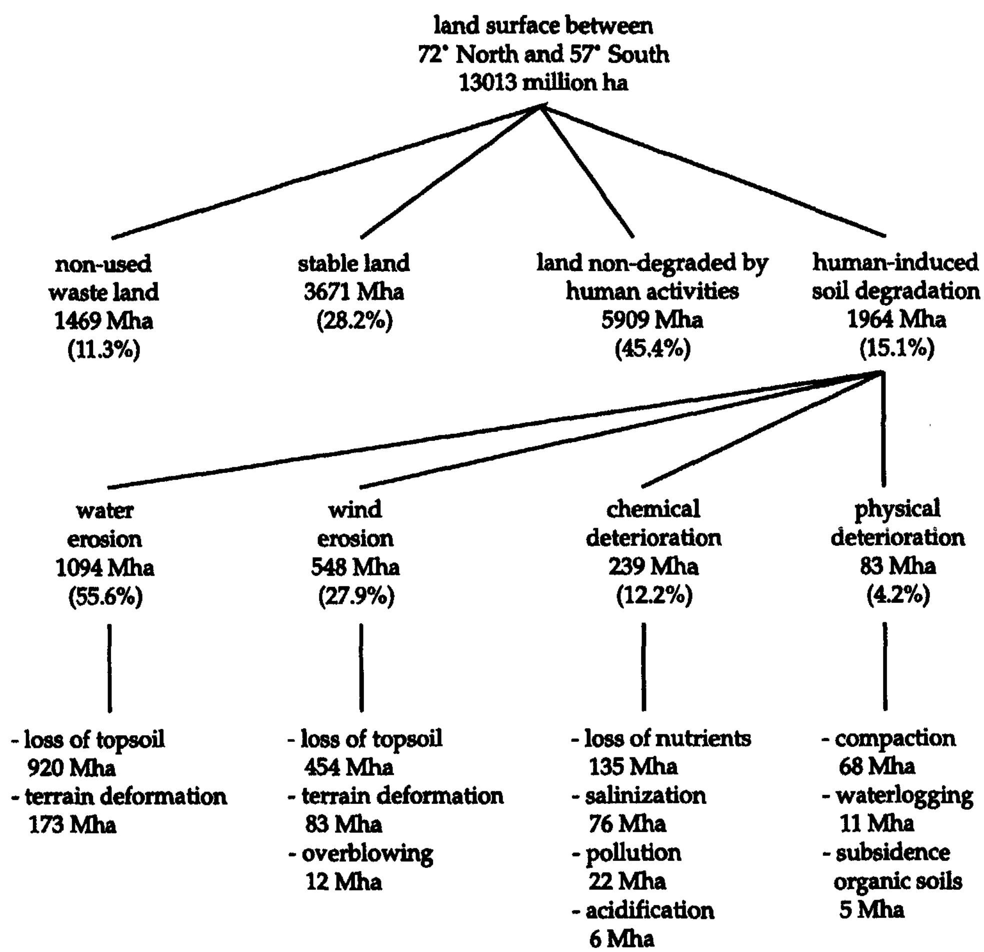
Water erosion is by far the most important type of soil degradation, occupying more than half the total area affected by human-induced soil degradation. On a world scale, the area affected by wind erosion occupies about one-third of the degraded land area. Chemical soil deterioration covers about 12 percent, while physical soil deterioration occupies a mere 4 percent.

When one looks at the different subtypes of soil degradation, loss of topsoil by water and wind erosion turns out to be by far the most important soil degradation problem. Loss of topsoil affects an area of 920 + 454 = 1.4 billion hectares, which equals about 70 percent of the total area affected by degradation. Loss of nutrients is the major subtype of chemical deterioration of the soils (135 million hectares, or about 7 percent of the degradation-affected area) followed by salinization (76 million hectares). Finally, compaction is by far the most important subtype of physical soil deterioration. It occupies worldwide about 68 million hectares.

Some notable differences exist in the importance of soil degradation and the relative importance of the various soil degradation categories on each of the continents. Soil degradation is most severe—both in an absolute and in a relative sense—in Asia. Out of the 2 billion hectares affected by soil degradation, 748 million are located in Asia. About 32 percent of the land area affected by human intervention in Asia suffers from soil degradation, as compared to 25 percent worldwide. Above average soil degradation is further observed in Central America (28 percent) and in Africa and Europe (26 percent each). In absolute size, Africa ranks second after Asia, having 494 million hectares that are affected by degradation.

The information provided by Oldeman, Van Engelen, and Pulles (1991) further indicates that water erosion is relatively more severe in Central America (74 percent of the degradation-affected area) and Australia (81 percent). In Central America, the problem associated with water erosion is not so much loss of topsoil (34 percent) as it is terrain deformation (40 percent). Wind erosion is relatively more important in Africa (38 percent of the total affected area) and North America (36 percent). Chemical deterioration is a major type of soil degradation in South America (29 percent of the degradation-affected area). The problem associated with it is loss of nutrients. About 50 percent (68 million hectares out of a total of 135 million) of the worldwide area affected by nutrient depletion is located on this continent. Most of the other areas affected by nutrient losses are located in Africa (45 million hectares, or 33 percent). Pollution is mainly a problem in Europe. Of

Figure 7-2. Terrain division and (sub)types of human-induced soil degradation



Source: Oldeman, van Engelen, and Pulles 1991.

the 21.8 million hectares affected by it, 18.6 million are located in Europe. Likewise, compaction (the main type of physical soil degradation) is largely a European problem. Out of the 68 million hectares suffering from compaction, 33 million can be found in Europe.

Four degrees of soil degradation were distinguished in drawing the GLASOD map:

- *Light.* The terrain has somewhat reduced productivity but is suitable for use in local farming systems. Restoration to full productivity is possible by modifying the management system.
- *Moderate.* The terrain has greatly reduced productivity but is still suitable for use in local farming systems. Major improvements (that are often beyond the means

of local farmers in developing countries) are required to restore productivity.

- *Strong.* The terrain cannot be reclaimed at the farm level. Major engineering work (and international assistance) is required to restore these terrains. Original biotic functions are largely destroyed.
- *Extreme.* The terrain cannot be reclaimed and is beyond restoration. Original biotic functions are fully destroyed.

According to Oldeman, van Engelen, and Pulles (1991, appendix, table 9), 38 percent of the total world area affected by soil degradation (2 billion hectares) suffers from a light degree of degradation, 46 percent from a moderate degree of degradation, 15 percent from strong degradation, and 0.5 percent from extreme degradation. Most of the land suffering from extreme degradation is located in Africa (5.2 million hectares) and Europe (3.1 million hectares). The associated problems are mainly loss of topsoil from water erosion and overblowing in Africa and terrain deformation caused by water erosion in Europe. Land area suffering from strong degradation is found largely in Africa (124 million hectares) and Asia (108 million hectares). The associated problem is particularly loss of topsoil caused by water erosion and, to a lesser degree in Asia, terrain deformation and salinization. More details on estimates of human-induced soil degradation per continent can be found in the appendix to the study of Oldeman, van Engelen, and Pulles (1991).

Notes

Some parts of this chapter draw on Heerink and others (1993). The authors wish to thank Petra Hellegers and Gerdien Meijerink for their assistance in preparing the section on price changes and soil degradation and the appendixes.

1. Trade disputes over health and safety standards are more likely than disputes over policies dealing with consumption pollution because of the inexact nature of their scientific evidence and other reasons (GATT 1992, pp. 31–33). The United States–European Community dispute over the use of growth hormones in beef provides a good example.
2. The importation of products with environmentally harmful production or processing methods is often referred to as "psychological spillovers." This section only deals with psychological spillovers to local environmental problems abroad. The impact of imports on the threatening extinction of species of animals (or plants) that live (or grow) abroad may also be called a psychological spillover (see, for example, Blackhurst and Subramanian 1992). The present analysis does not apply to such psychological spillovers with a global dimension.
3. In addition, strong doubts have been cast on the validity of the underlying basic, neoclassical assumptions and on the environmental benefits of trade liberalization when these assumptions do not hold. See Ekins, Folke, and Costanza (1994) for a review.
4. See also Anderson and Strutt (1994) for a discussion of the desirability of adding an environmental dimension to existing models of agricultural trade liberalization and the problems involved in doing so.
5. Anderson also considers a liberalization scenario with only the protectionist food policies in advanced industrial countries removed. The corresponding simulation results are not discussed here (see Anderson 1992a, 1992b).
6. A notable exception to this general tendency is China.
7. Lutz's analysis of environmental effects of agricultural trade liberalization draws on simulation results obtained by different agricultural trade models.
8. We only consider the asserted environmental effects. Technical aspects of the models, such as the relevance of the per-

fect markets assumption for low-income countries and the problems involved in modeling technical change, are not discussed here.

9. These benign environmental effects provide a strong argument in favor of fertilizer subsidization in countries where nutrient depletion is a major problem. Such fertilizer subsidies should preferably be combined with policies aimed at improving the accessibility and reducing the distribution costs of fertilizer (Heerink and Kuyvenhoven 1993). This conclusion differs from the total rejection of farm input subsidies by Repetto (1989), Anderson (1992a, 1992b), and Lutz (1992).

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8

Energy Sector Policy and the Environment: A Case Study of Sri Lanka

Peter Meier, Mohan Munasinghe, and Tilak Siyambalapitiya

This study[1] represents a further stage in the multi-criteria approach to energy and environmental planning that was developed in Meier and Munasinghe (1994). This earlier work has been broadened to include other important energy subsectors such as fuel use in road transportation. More important, price and tax policy options are also included in the analysis, through the addition of financial dimensions to the earlier models—whose scope had been limited to technoeconomic considerations.

Introduction

The environmental impacts of specific energy investments are fairly well recognized. Environmental impact assessments of energy projects in developing countries have become a routine and integral part of the Bank's policies to promote sustainable development. Much less well understood are the linkages between broader sectoral policies and the environment. For example, the environmental consequences of energy sector pricing reforms that have become a common component of structural adjustment lending remain largely unexplored. Similarly, effective procedures for incorporating environmental concerns into energy and electricity sector planning are not well established beyond some routinely affirmed general principles about the importance of economic efficiency, and the presumption that the environmental impacts of an economically efficient energy sector will be less than an energy sector characterized by subsidized prices and technological inefficiency, such as inordinately high transmission and distribution (T&D) losses, poor heat rates of thermal electric generation plants, and so on.

The effects of direct environmental constraints on sectoral policy are equally poorly understood, except in the general sense that if energy costs fully reflect the environmental damages of energy production, optimal resource allocation is ensured. For example, not enough work has been done to analyze alternative policy options for achieving greenhouse gas (GHG) emission reductions in developing countries, beyond routine statements about the importance of efficient resource use, and assertions that renewable energy and natural gas should replace coal. Indeed, studies of this subject that have appeared are based on highly aggregated macro models that offer little guidance on the specific measures to be undertaken at the sectoral level.

In this chapter we analyze and quantify representative examples of both types of linkages using Sri Lanka as a case study. First, as an example of a sectorwide policy with potentially broad environmental consequences, we examine electricity price reform. Second, as an example of a direct environmental constraint with broad energy sector and economywide consequences, we analyze options for greenhouse gas emission reductions to meet potential targets mandated by the World Climate Convention.

Electricity Pricing Reform

The economic rationale for efficient pricing of electricity is well established, and has been documented in many studies (see, for example, Munasinghe 1990). Reforms to eliminate subsidies and to raise tariffs in order to improve the financial health of electric utilities have been proposed and implemented in numerous instances.[2] Indeed, covenants between the Bank and its borrowers which provide for tariff increases to generate sufficient revenue to meet self financing targets or the rate of return on equity have become an increasingly frequent part of Bank power sector loans.

Many methodological problems arise in evaluating the environmental consequences of such sectoral policies. Although the environmental benefits of an efficient pricing policy are perhaps intuitive, in practice the relationships are quite complex, and the magnitude of the effects dependent on a variety of specific assumptions. If higher prices based, for example, on established long-run marginal cost (LRMC) pricing principles served simply to depress demand, relative to subsidized prices, then merit order dispatch would be expected to result in reduced use of older, less efficient thermal plants. Therefore, pollutant emissions from thermal plants would certainly be lower. Reduced demand will also affect the least-cost expansion path, so that the addition of more efficient units is delayed. This may result in older units being dispatched more than would otherwise be the case, resulting in an increase in emissions. The extent to which the latter effect is offset by a lower generation requirement is an empirical one, and can only be answered by looking at a specific case.

Part of the problem in estimating the benefits of pricing policy in an actual case is also analytical. Financial models of the electric power sector have long been used in project appraisal work. It is standard practice to use such models, typically LOTUS 123 spreadsheets, to examine the financial impacts of alternative tariffs and financial covenants. In the typical case, we examine either by trial and error, or by an appropriate iterative computation, what the tariff must be to meet some specific target for the rate of return on equity or on fixed revalued assets, or for the percentage of self financing of the future investment program. These estimates then become part of the financial covenants that are entered into as a condition for lending by an external donor.

Unfortunately, almost all the standard financial models take the technical data as exogenous inputs derived from other, more detailed engineering models. For example, the fuel bill in the income statement is taken from a production costing model, the debt service assumptions are taken from the capacity expansion model, and so forth. It thus becomes extremely difficult to assess the feedback that arises from changes in the tariff, because the detailed models that provide the technical inputs are not directly linked. Furthermore, in many utilities the detailed models are run by different departments with little or no attempt to ensure consistency.

Greenhouse Gas Emission Reductions

With the agreement on the World Climate Convention signed by more than one hundred countries at the recent Earth Summit in Rio de Janeiro, the practical problems of how the obligations to reduce greenhouse gas (GHG) emissions can be met in the most cost effective manner require urgent attention, particularly in developing countries which have limited options. Simply put, there is a very wide range of potential policy options which might be used, ranging from direct technology substitution (replacing coal burning power plants with wind generating plants, for example) to indirect pricing and taxation policies, such as the imposition of carbon taxes on fuels, or the imposition of emissions taxes. How this wide range of options is to be evaluated on a consistent basis, and how the many tradeoffs are to be assessed in a systemic manner, is still subject to considerable question.

Most attempts to examine the broad policy implications of GHG emission strategies have stressed the long term choices, using highly aggregated general equilibrium models of one kind or another. Manne and Richels (1990) for the case of the United States, Goto and Sawa (1993) for the case of Japan, or Proost and V. Regemorter (1992) for the case of Belgium, typify the genre: time scales which run in some cases to the year 2100, new technologies whose earliest introduction at a significant level is 2010 and beyond, and highly aggregated sectoral descriptions of the economy.[3]

The results of such highly aggregated, long term models may provide useful insights into general long term policies, and indeed generally tend to show that the losses to gross domestic product (GDP) growth resulting from a fairly wide range of carbon emission restriction scenarios are rather small. As noted by Hogan (1990), the Manne-Richels calculations suggest that stabilizing carbon dioxide emissions at 80 percent of the 1990 level accounts for about 5 percent of the total macroeconomic consumption through the next century—about the same order of magnitude of recent defense expenditures in the United States, but less than the 20 percent of the level of defense expenditures in the former Soviet Union.[4]

Whether such conclusions are in any way relevant to the smaller developing countries, particularly lower income, oil importing countries, is in some doubt. As we shall see below, there is no chance whatsoever that a country such as Sri Lanka could stabilize its carbon dioxide emissions at the present level, or even at twice the present level. Even if electricity growth could be entirely accommodated by renewable energy—which, in light of projected electricity demand growth of 7 percent per year, requires heroic assumptions about the feasibility of building large hydro plants—the anticipated growth in transportation sector fuel consumption (even under highly optimistic expectations about mass transit and fuel efficient vehicles) precludes stabilization of carbon dioxide emissions in the near future.

In what appears to be an early analysis of GHG emissions for a developing country, Blitzer and others (1993) apply a general equilibrium model to Egypt, with— six non-energy sectors, and four energy sectors—crude oil, natural gas, petroleum products, and electricity. GDP losses are much higher than those estimated for the developed countries: 4.5 percent for a 20 percent reduction in annual carbon emissions to 22 percent for a 40 percent reduction more than the base case—which still implies a significant increase in actual carbon dioxide emissions. Even these results, however, are for a country for which the assumed backstop technologies—natural gas powered transport and nuclear power—are feasible options. Sri Lanka, like many low-income countries, has no natural gas resources of its own, and nuclear power is not an option for the foreseeable future.

None of this implies that reduction in GHG emissions should be ignored in Sri Lanka. It does imply, however, a different way of approaching the problem. Rather than imposing emission constraints defined on an *a priori* basis, and attempting to determine what GDP growth losses are associated with such particular levels of GHG emission reductions, we pose a much narrower set of questions. The latter are more relevant to short- and medium-term decisionmaking—that is, can we find expansion paths for the energy sector which meet both the goals of economic efficiency and environmental sustainability?

A somewhat different approach has been taken by Burgess (1990) and by Larsen (1993). Addressing merely the effect of eliminating price subsidies, these studies estimate the level of reduction in GHG emissions by application of an assumed price elasticity to the difference between the subsidized and unsubsidized price. Burgess uses the difference between actual average cost of electricity and the estimated long-run marginal cost (LRMC), applies an assumed long run price elasticity of minus one, and estimates the reduction in GHG emissions for eleven countries, including the United States, China, India, and some small developing countries, including Tanzania and Peru. Not surprisingly, the bulk of the total carbon emission savings (124 million tons per year) comes from coal fuel savings, of which India accounts for 11.9 tons, China 26.6 tons, and the United States 85.4 tons.[5] Larsen does the same analysis but from the perspective of fuel prices, and applies estimated own and cross price elasticities for the different fossil fuels to the difference between an appropriately adjusted border price and the domestic subsidized fuel price, and, more significantly, includes the countries of the former Soviet Union and Eastern Europe. In this analysis, the former Soviet Union (917 million tons per year) and Poland (105.2 million tons per year) dominate the results. Indeed, the combined estimated effect in India (54 million tons of carbon dioxide), and China (45.4 million tons of carbon dioxide) together is less than that for Poland.

Such studies certainly provide some estimates of the efficacy of pricing instruments, but tell us little about the actual impacts on consumers and, therefore, the barriers likely to be encountered if the policy reforms were to be implemented. Clearly, as relative fuel prices change, hydroelectricity may become more attractive for electricity generation—bringing its own set of significant environmental impacts. Moreover, shifts from coal to natural gas may well be desirable not just from the perspective of carbon dioxide emissions, but also from the perspective of reducing sulfur dioxide, nitrous oxides, and trace metals. This is small comfort, however, for countries such as Sri Lanka that have no natural gas resources of their own. In any event, countries for which imported coal is the least-cost fuel for baseload thermal electricity generation (as is the case for Sri Lanka), have no coal price subsidies to eliminate.

Our assessment of the literature suggests that whatever may be the value of very broad, long-range policy assessments at the macro level, there is a much more urgent need to move to detailed and specific study of the more immediate short- to medium-term issues. In order to move beyond affirmation of broad policy principles to implementation of specific programs, there is a need to provide decisionmakers with estimates of the specific effects of alternative options.

Yet even this more limited objective proves to be quite difficult to achieve. Of those who have attempted to examine the detailed issues of policy and technology implementation, almost all have centered on generic technology rankings, in which the ranking criterion is the cost of GHG emissions anticipated from the introduction of some particular technology, generally expressed as U.S. dollars per ton.[6] Although such costs can be calculated in a generally straightforward manner for specific technologies, how can the costs of such technology interventions compare with those of more broad-based economywide price and tax policies? Moreover, particularly in the case of electric sector technologies, the proposition that technologies can be evaluated in isolation of the systems context is extremely tenuous, because of the interactions which occur through the system load curve. For example, the effect of load management and transmission and distribution (T&D) loss reduction when implemented together is demonstrably less than the sum of the impacts of each of these technologies evaluated alone.

It is fairly clear, therefore, that a consistent assessment of policy options for GHG emissions reduction requires a systemic evaluation—which in turn requires some comprehensive representation of the technical, environmental, economic, and financial characteristics of the energy system. This is a major challenge, insofar as most energy models presently available tend to focus on only part of the problem. Most attempts at providing an environmental impact assessment capability to energy models are little more than add on modules to calculate residuals.[7] For example, the Wien Automatic System Planning (WASP) model is very widely used in developing countries for optimizing the capacity expansion path of the electric sector.[8] To this has now been added the IMPACTS module, which permits calculation of the residuals and pollution control costs associated with least-cost solutions of WASP.[9] The TEMIS model, developed by the German Oko Institute,[10] is of a similar genre, permitting calculations to be made of a wide range of pollutant emissions associated with a given energy facility, including those associated with the upstream fuel cycle.

In the case of GHG emissions, the fact that such models are limited to residuals is perhaps not very serious. Certainly there is very little reason to believe that the actual impacts of other pollutants, such as sulfur dioxide and particulates, are linearly related to emissions levels. More serious from our perspective, however, is the fact that such models are of limited use for assessing economywide price and tax policies on a consistent basis, because they generally lack integration with financial models, and energy demands tend to be defined exogenously.

Several additional methodological problems relate to the workings of the Global Environment Facility (GEF). This is the funding mechanism, on an interim basis, for providing financial resources needed by developing countries to meet the full incremental costs incurred in complying with their obligations under the World Climate Convention.

If the GEF is to fund the incremental costs of GHG reduction measures, this presupposes that a baseline can be unambiguously defined, against which such incremental costs be defined. One obvious approach here is to define the baseline as the least-cost solution to expansion of the energy system. As is now fairly well recognized in the case of electric sector expansion, the concept of least-cost is extremely fragile.[11] Such a solution may be valid only for a very narrow band of input assumptions. If these assumptions prove to be different, then an investment program predicated upon the least-cost plan may ultimately be distinctly non-optimal. In short, any deterministic definition of incremental cost will run into a range of practical operational difficulties.

Equally difficult is the treatment of joint products. Options which reduce GHG emissions may also provide significant changes in other pollutants whose impacts are of a quite different scale. For example, the substitution of renewable energy technologies for coal will reduce not just carbon dioxide emissions (which would provide a global benefit) but also sulfur dioxide and particulate emissions, which bring a reduction in local environmental damages. On the other hand, the increased use of renewable energy technologies, such as hydroelectric generation, which also reduce carbon dioxide emissions, may also impose new and different local environmental costs, such as loss of biodiversity associated with reservoir inundation.[12]

Approach

In this report we address these various analytical and methodological issues by the application of an integrated sectorwide spreadsheet model (see figure 8–1).

At the core of the model stands a conventional financial representation of the electric utility and the refinery—with the usual income statement, sources and uses of funds, and balance sheet. The model allows the user to specify one or more balance sheet ratios as the criteria for setting the level of the tariff—such as return on equity or assets, self financing ratio, and so on. The financial model is then linked to technical representation of the energy sector, with demand and supply modules for each major subsector. In the case of the electric sector, for example, this would include merit order dispatching and capacity expansion, and be driven by an econometrically specified demand model, which in turn takes prices from the current tariff in the financial statements. The model is closed by passing the investment requirements for capacity expansion back to the financial module.[13] Thus, adjustments in the capacity expansion plan (in response to lower demands caused by higher prices, for example) feed back automatically into the asset and liability accounts in the financial statements. We thus achieve a completely consistent set of prices, demands, technical sector configuration, investment, and financial representations of the major sector institutions which permits simulation of a wide range of policy options. The model is described in detail in a separate report (Meier 1995).[14]

Scope

In the second section of this chapter, we will review the main options for the energy sector. Although the emphasis here is on the electric and road transportation sectors—the main areas where significant greenhouse emission reductions can be attained—biomass still accounts for 70 percent of the total primary energy used in Sri Lanka.

The environmental impacts of electricity price reform will be presented in the third section of this chapter. The focus here is to assess the effects in terms of different approaches to tariff setting: one based on financial criteria, by setting the tariff equal to that required in order to meet specific targets for balance sheet ratios; and the other based on economic criteria, by setting the tariff equal to long-run marginal costs.

In the fourth section of this chapter we examine greenhouse gas emission reduction options. The focus here is on a comparison of different approaches which might be used, including the pricing policy options already examined earlier in this chapter. We will also look at a variety of technology and other policy options, ranging from the use of clean coal technology in the electric sector, to inspection and maintenance programs for urban buses and trucks in the road transportation sector.

In the fifth section of this chapter is a discussion on how to account for risk and uncertainty. This is an exceptionally important topic, given the many uncertainties encountered in energy and environmental planning. The search here is to identify options robust to sources of risk and uncertainty beyond the decisionmakers' control. The conclusions are summarized in the final section of this chapter.

Energy Sector Options

The salient features of Sri Lanka's energy situation are displayed in figure 8.2. The most notable feature is that 70 percent of primary energy is still biomass, and only 20 percent of the total energy is from oil. With most of the biomass consumed for household cooking, this form of energy also accounts for the largest share of end use consumption. In this report we are concerned primarily with the electricity and road transportation sectors, which together account for almost 80 percent of the commercial energy consumption. Next we review the main features of these two sectors and define some of the technology and policy options that have a major bearing on their environmental impacts.

The Electricity Sector

The present installed capacity in Sri Lanka is 1,225 megawatts, of which 1,115 megawatts is hydro, the balance consisting of combustion turbines (108 megawatts), diesel (64 megawatts) and a 44 megawatts oil fired steam plant. In 1992, generation was 3,377 gigawatt hours (gwh), with a transmission and distribution (T&D) loss rate of 18.8 percent of total generation.[15] The rate of demand growth during the next decade is expected to be between 7 and 9 percent.

Assuming no discoveries of oil or natural gas, the conventional wisdom is that for the next twenty years the generation options for Sri Lanka are quite limited. Although substantial hydropower resources could be developed, the remaining sites are limited in size, and have substantially higher costs than alternative options (see table 8–1). The least-cost system expansion studies conducted annually by the Ceylon Electricity Board (CEB) show that the least-cost plan is to begin building coal fired baseload stations using imported Australian coal by the beginning of the next decade.

Table 8-1: Specific generation costs

project/plant	capacity,Mw	specific costs, US cents/Kwh
remaining hydro projects		
Upper Kotmale	123	4.55
Kukule (run-of-river)	70	5.25
Ging ganga	49	5.42
Belihul oya	17	6.18
Broadlands	40	7.45
Moragolla	27	7.79
Uma oya	150	8.03
thermal		
coal (70 percent PF)	300	5.9
diesel (70 percent PF)	20	6.2
Z combustion turbine (20 percent PF)	22	11.45

Source: CEB Report on Long Term Generation Expansion Planning Studies, 1993-2007, October 1992.

The remaining large hydro plants, such as the high dam variant of the Kukule project, involve substantial resettlement and removal of forest area, and are likely to be fiercely opposed by environmentalists. As a matter of practicality, expansion of conventional hydro is likely to be limited to smaller run-of-river schemes such as Broadlands, and the run-of-river variant of the Kukule project.[16]

Yet even some run-of-river schemes will likely encounter fierce opposition. The original design for the proposed Talawakelle run-of-river plant, part of a proposed hydro development scheme on the Upper Kotmale, would cut off river flow from the St. Clair's waterfall, a well-known scenic attraction. Nuclear power is not likely to be a feasible option for Sri Lanka for some time, even apart from the environmental issues. Present indications are that even under very high rates of demand growth, it would be at least 2030 before the system is of a sufficient size to accommodate a 500 megawatts to 600 megawatts nuclear unit.[17]

There are substantial environmental concerns associated with the introduction of coal fired power stations in Sri Lanka. The environmental impact assessment prepared for a proposed coal burning station at Trincomalee, in the northeast (see map, figure 8–3), revealed a range of important issues. These issues range from impacts on the aquatic ecosystems of Trincomalee Bay caused by the discharge of thermal effluents, to air pollution concerns caused by particulate and sulfur oxide emissions. After great controversy in the mid 1980s,[18] the necessary permits could not be obtained. Ultimately, the deciding factor was the impact of discharging large volumes of heated water into the relatively shallow waters of a small bay near the proposed site. As a result, attention shifted to the south coast as a possible site. This proposal has also encountered opposition, and most recently attention has shifted back to the Trincomalee site.[19]

As to the possibility of domestic fossil fuels, although it is true that India has made some oil finds approximately fifteen miles north of the Sri Lanka maritime border in the Palk Straits, these are as yet of unknown commercial potential. As one recent study on this question concluded "...one can only repeat the dictum: there are no known resources of oil, gas, or coal in Sri Lanka!" (Perera 1992). There are some known peat deposits at Muthurajawela, but the usable quantities are small and of poor quality[20]. It is clear that during the next fifteen to twenty years any fossil fuels used for electricity generation will be imported.[21]

In the absence of domestic natural gas, is it possible that imported liquid natural gas (LNG) could be an alternative to coal? Gas fueled combined cycle plants have many advantages: relatively low capital costs (about US$600 per kilowatt), a thermal efficiency of around 50 percent,[22] compared to 40 percent for coal based generation, much faster construction times, and significantly lower environmental impacts, ranging from an absence of solid waste impacts to much lower GHG emissions, as well as significantly sulphur oxides and particulates.

The costs of setting up the necessary gas importation, storage, and transport facilities are extremely high, however. Some indication of the necessary scale of generation that is necessary to offset these infrastructure costs can be gauged from the proposed ENRON project in India on the west coast of Maharashtra near Bombay. The original proposal was for 2,200 megawatts of capacity, with LNG to be imported from the Persian Gulf. In light of the many difficulties in implementing a project of this scale, a phased project implementation subsequently replaced the original proposal. The first phase of 600 megawatts is to be fueled by imported fuel oil, though with a capability to use gas at a later stage. Certainly for the foreseeable future, an imported LNG option must be regarded as extremely unlikely for a small country like Sri Lanka.

An oil based combined cycle plant has been included as one of the options in CEB's generation planning studies for some years, but the heavy diesel oil that would be necessary is relatively expensive. For this reason, this option does not enter the least-cost plan.

A more likely alternative is a steam cycle plant using fuel oil, but this option does not appear to have been examined in any great detail by the CEB. Capital costs are likely to be significantly lower, but any large-scale importation of heavy fuel oil will require significant infrastructure development. The various capital cost assumptions are summarized in table 8–2.

Thus it is fair to say that the conventional, supply side options are quite limited. The main options for the next 20 years are diesels running on heavy fuel oil, steam turbines using heavy fuel oil or coal, and some run-of-river hydro. Fortunately, there are a wide variety of renewable and demand side options that may alleviate this situation, ranging from good prospects for wind generation on the south coast[23] to a substantial, although as yet unverified, potential for demand side management options.[24]

Table 8–2: Capital Cost Assumption

technology	capital cost, US$/Kw
Coal	1,420
Coal with FGD	1,600
Diesels (10Mw units)	1,188
Oil steam	1,250
Natural gas	1,000
Oil combined cycle	1,061
Natural gas combined cycle	800
Combustion turbines	622

Technology Options in the Electricity Sector

We now turn to a brief discussion of some of the other technology options considered in this study. The objective is not so much to define all possible options, as much as it is to select a set of representative technologies and fuel choice options. For example, without comprehensive demand side management (DSM) study, the full DSM potential cannot be established. We can select one or two representative measures for which data can be extrapolated from recent studies conducted in other countries, however, such as energy efficient refrigerators, and compact fluorescent lighting in the domestic sector. Similarly, wind energy and mini-hydro plants are selected as representative renewable energy options.

WIND ENERGY

Although there are a number of renewable energy technologies that may be considered for Sri Lanka, the technology with the most immediate possibilities is wind energy. Utility scale solar thermal plants are potentially attractive in the more distant future, but for the next ten to fifteen years the costs are still expected to be very high.[25] PhotovoltAICs probably have the greatest potential in remote rural areas that do not have grid access. The wind feasibility assessment recently completed for the southern lowlands of Sri Lanka estimated the ultimate potential at some 300 megawatts. In this study we assume that three 50 megawatts wind farms will be built in this area in the years 1998-06.[26] The most important finding of the monitoring program conducted at the site concerns the hourly variations, which show a distinct peak during the afternoon hours (See figure 8–4). Unfortunately, this peak is not coincident with the evening peak in the load curve. There are also very strong seasonal variations: during the summer monsoon period monthly output for a 50 megawatts facility is estimated at about ten gwh per month, falling to a low of about two and a half gwh per month in March and November. Consequently, wind plants will do little to reduce installed capacity requirements, but will serve primarily to displace thermal power, and to reduce expected deficits in dry years.[27]

MINI-HYDRO

The Gesellschaft fuer Technische Zusammenarbeit (GTZ) electricity masterplan identified a series of potential mini-hydro sites. In this option we assume that the four with the lowest specific generation cost will be implemented in the 1998-02 time frame, to provide a total additional mini-hydro capacity of 30 megawatts.[28]

DSM

A systematic assessment of DSM options has yet to be conducted in Sri Lanka. Indeed, comprehensive DSM assessments have been conducted for very few developing countries to date.[29] Nevertheless, there are indications that there exist some significant opportunities for the introduction of energy efficient end use technologies in Sri Lanka. Both an internal World Bank power system efficiency study of Sri Lanka in 1983 and the GTZ masterplan made some preliminary estimates of the potential for load management and energy conservation by the systematic replacement of incandescent lights by fluorescent lights.[30]

In this study we examine two specific technologies to improve the efficiency of electricity use: increased penetration of compact fluorescent lighting in the domestic and commercial sectors,[31] and the introduction of energy efficient refrigerators.[32] The former is largely a load management measure, with very large megawatts savings during the evening peak, but relatively modest energy savings.[33] The latter is largely an energy saving measure, however, with little impact on the peak. As can be seen from figure 8–5, there is a very pronounced evening peak that coincides with the hours immediately after sundown, indicative of the importance of the lighting load.[34]

No coal

A no coal option has been evaluated by the CEB annual generation planning studies for some time, although the rationale had less to do with reducing GHG emissions than with the extent of public opposition to large thermal plants located in the coastal zone. Obviously, more hydro plants will be built in this option, and many more diesel plants.

Pressurized fluidized bed combustion-combined cycle (PFBC-CC)

Of the many clean coal technologies currently in the demonstration stage, PFBC-CC is perhaps the most promising.[35] With combustion typically at ten to fifteen atmospheres, hot combustion gases can be fed directly to a combustion turbine, thus increasing overall efficiency. Figure 8–6 shows a schematic for a PFBC plant, as compared to a conventional pulverized coal plant with flue gas desulfurization (FGD). A typical 74 megawatts unit, such as the one being built at Tidd in Ohio, might have a 58 megawatts steam turbine and a 16 megawatts combustion turbine. The result is that even if the pressurized combustor is more expensive on a dollar per kilowatt basis than a conventional boiler, it is offset by a cheaper dollar per kilowatt for the combustion turbine portion. As a result, the overall capital cost will not be very much more expensive than a conventional coal unit, especially one with an FGD system.[36]

The much higher overall efficiency makes this a particularly attractive technology where coal must be imported, as in Sri Lanka. Heat rates will be 10 to 15 percent higher than for conventional PC units without FGD systems, and 20 percent better than FGD fitted units of comparable sulfur removal performance. Demonstration results for environmental emissions have exceeded expectations. At the Tidd PFBC unit in Ohio, NOx emissions, expected to be half a pound per 10^6 British thermal units (BTU), have been in the range 0.15 to 0.18 pounds per 10^6 BTU, and sulfur retention rates, predicted at 90 percent, have averaged 93 percent.

T&D loss reduction

As can be seen from figure 8–7, the progress in reducing losses to the present 12 percent target set by CEB has been much slower than anticipated. As recently as 1989 it was projected that the 12 percent target would be attained by 1993, yet by 1992 that target had been delayed to 1996. Given the lack of progress during the past few years (in 1991 losses actually increased), there is some question as to whether even this target can be attained.[37]

MAXIMUM HYDRO

Maximum reduction of greenhouse gases is achieved by maximum use of hydro plants.[38] Because of the high costs, this has again to be forced into the solution: in this scenario all of the remaining major hydro plants in Sri Lanka are assumed to be built by 2011.[39]

CLEAN FUELS AND FGD

Finally we examine the possibility of imposing flue gas desulfurization systems (FGD) on coal plants, and of using low sulfur oil or coal. The existing refinery at Sapugaskanda

Table 8–3: Summary of electricity sector options

	option	comments	
1	wind energy	305Mw total	wind
2	mini-hydro		minihy
3	DSM: energy efficient refrigerators		EEF
4	DSM: compact fluorescents		CFL
5	T&D loss reduction	10 percent T&D loss goal (in place of 12 percent) by 2000.	TD+
6		12 percent goal delayed to 2003	T&D-
8	max hydro	builds both reservoirs in the Upper Kotmale project; 144Mw high dam version of Kukule.	maxHy
9	clean coal technology	pressurized fluidized bed combustion-combined cycle units; assumed for all coal units after 2000:	PFBC
10		with pessimistic capital cost assumptions	PFBC--
11	clean fuels	use imported low-sulfur residual oil for diesels (0.5 percent S by weight rather than 2.5 percentS).	low S oil
12		use low sulfur (0.5 percent) coal (rather than 1 percent S coal)	low S coal
13	FGD systems	model free to chose optimal generation mix; coal plants must have FGD systems.	FGD
14		FGD systems forced onto basecase solution	**FGD
15	no coal	model free to choose least-cost combination of diesels +hydro	noCoal

does not have fuel oil desulfurization facilities, and the specification of the heavy residual oil used for diesel units is 3.5 percent sulfur by weight. During the past decade, however, and especially due to the recent refinery rehabilitation, increasing amounts of lower sulfur Malaysian crude have been used, so the actual sulfur content has been substantially below specification. In this study we assume 2.5 percent sulfur by weight. Low sulfur fuel oil (0.5 percent by weight) would need to be imported from Singapore spot markets, for which the premium is about US$25 per ton.

The Road Transport Sector

During the past decade motor vehicle traffic in Sri Lanka has risen very fast. Particularly in the Colombo metropolitan area, problems of traffic congestion, and of related environmental concerns such as lead and particulate emissions, have begun to emerge.[40] Urban air quality is a priority issue in the national environmental action plan (NEAP). The Metropolitan Environmental Improvement Programme (MEIP) has recently issued an action plan for Colombo in which the transportation sector is a major target. Combustion of gasoline and diesel fuel is currently the largest source of carbon emissions in Sri Lanka.[41] Even if large-scale generation of electricity from coal commences in the late 1990s,[42] the transportation sector will continue to represent a major source of total national greenhouse gas (GHG) emissions.

Unfortunately, despite the importance of the sector to both energy consumption and air quality, few rigorous studies of the transport sector are available. This shortcoming is hardly unique to Sri Lanka, for transport is almost universally among the least understood of energy subsectors. This is largely due to the lack of good data. Even estimates of the most basic indicators—such as the size of the vehicle fleet—are often subject to great uncertainty,[43] and sources of data that are available frequently show major discrepancies.

Sri Lanka is quite typical in this respect. For example, a report (USAID 1991) prepared for the Natural Resources and Environmental Policy Project (NAREPP) estimates the number of automobiles in 1990 as 205,078. The MEIP action plan puts the number at 128,815, although the estimate of the Transport Planning and Studies Center puts the number at 92,962 (ESCAP 1992).

Reconciling the vehicle fleet, fuel economy, and vehicle kilometer traveled in each vehicle class with actual fuel consumption proves to be very difficult. The basic problem is that despite a huge increase in the vehicle fleet, and rapidly increasing congestion in Colombo, the increase in fuel consumption, which is known with much greater confidence than any of the transport fleet characteristics, has been quite modest[44] (see figure 8–8). Thus, if we apply what appear to be reasonable estimates of vehicle fuel economy and miles traveled per vehicle to typical estimates of the motor vehicle fleet, the implied estimate of fuel consumption proves to exceed actual consumption by a significant margin. In one study of the environmental impacts of road

Table 8–4: Annual Growth Rates in the Motor Vehicle Fleet (in percent)

	1973-1977	1977-1980	1980-1990
cars	0.4	7.6	5
taxis	0.9	13.3	5.1
pickups	12.6	29.7	8.2
heavy buses	5.8	7.5	1.2
other buses	27.5	86	20.2
truck	-4.6	20.6	7.8
3-wheelers		135.6	28.7
motorcycle	62	149.5	22.5
total	1.3	26.04	14.03

Source: ESCAP estimates

transport in Sri Lanka the estimate exceeded actual consumption by a factor of six.

The essential trends are easy enough to understand. Prior to the liberalization of the economy in 1978, growth in the vehicle fleet was constrained by import quotas. In the last three years before liberalization, the growth rate in the vehicle fleet was only 1.3 percent per year (see table 8–4).

With the decontrol of the economy in 1978, and the lifting of import quotas, the economy expanded very rapidly, and the vehicle fleet grew dramatically, with a surge in new vehicle registrations (see figure 8–9), resulting in sharp growth of the fleet. Another significant event of this period was the decision by the government to break the monopoly of the public transport authorities. As a result, private buses quickly captured a rapidly growing share of this market segment. Between 1977 and 1980, the number of these buses rose from 1,300 to 8,100, with a concomitant impact on the consumption of diesel fuel.

Rates of growth settled down after their surge in the late 1970s. Nevertheless, for three vehicle categories—private buses, three wheelers, and motorcycles—average growth rates of more than 20 percent per year during the decade resulted in a profound shift in the vehicle mix. Thus, as shown in figure 8–10, an increasing share of the non-bus passenger kilometers traveled has shifted to motorcycles.[45]

Although rapid growth in three wheelers and motorcycles has completely transformed the face of urban motor traffic, their inherent fuel efficiency has meant that growth in fuel demand has been much more modest than if automobiles had satisfied the implied transportation demand. Another way of putting this is that there has been a sharp drop in the amount of fuel consumed per vehicle, as illustrated in figure 8–11. This is a phenomenon that is far from unique to Sri Lanka: indeed, given the differences in GDP per capita, it is remarkable how similar are comparable statistics from Thailand.[46]

Perhaps the most important determinant of future pollutant emissions in the transport sector is the fraction of passenger miles that are provided by urban mass transit. As indicated in figure 8–12, the share of traffic in cars and motorcycles declined from 10 percent in 1975, to around 5 percent by the early 1980s, largely a result of sharp increases in gasoline price.[47] Since then, however, motorcycles have captured an increasing share, and bus transport is back at about a 90 percent share.

The magnitude of fuel consumption and hence GHG emissions from the transport sector will be subject to a large number of policy variables. Some of them relate to fundamental decisions about the modal mix, particularly in Colombo. They include such policy questions as whether or not the railways should be electrified, at what point the major intercity and Colombo access roads should be upgraded (plans for the country's first expressway, from the airport into Colombo, are at an advanced stage), or the extent to which new measures are to be taken to reduce urban congestion in Colombo.

For the moment, the impact of any such major initiatives must be regarded as somewhat speculative, and beyond the scope of this report. We are limiting ourselves, for the moment, to an assessment of the more readily quantified trends and policy linkages that relate to fuel efficiency and the vehicle mix. In particular, we are examining some of the measures that are being proposed under the national environmental action plan, and the action plan for air quality management in the Colombo metropolitan area. Many of these measures, such as vehicle inspection and maintenance programs, have beneficial effects not just on the emissions of the pollutants of immediate interest—hydrocarbons, particulates and lead—but also on the efficiency of fuel consumption, and therefore on GHG emissions as well. Table 8–5 lists some of the main recommendations of the clean air action plan, and their potential impact on GHG emissions.

Unfortunately, the action plan provides no information at all on the costs of the recommended programs. These may in fact be sig-

Table 8–5: GHG Emission Consequences of Selected Measures in the Colombo Air Quality Management Action Plan

According to the MEIP, about 40 percent of motorcycles are of the 2-stroke type. These have higher emissions, but lower fuel economy than 4-stroke motorcycles. A larger share of 4-stroke motorcycles therefore implies a reduction in GHG emissions.	
Vehicle inspection and improved maintenance programs (particularly to reduce particulate emissions from buses and trucks)	I/M will also result in fuel economy improvements, reported in the literature to be from zero to 7 percent. USEPA assumes 3.5 percent, which is probably conservative for a developing country where vehicles are typically in much poorer condition than in the USA. In this study, therefore, we assume an improvement of 5 percent.
unleaded gasoline for reduction of lead emissions	Without a detailed study of refinery operations, difficult to predict. If octane enhancement comes from running reformers at higher severity, refinery fuel consumption and hence GHG emissions increase. In this study we assume no impact on GHG emissions for this measure.
reducing/cleaning up 2-stroke motorcycles	

Table 8–6: Transportation Sector Scenarios

policy measure	figure legends	comments on assumptions
vehicle inspection/maintenance program	VI/M	public buses covered by 1995, private buses by 1997, trucks by 1999 and automobiles by 2001. 5 percent improvement in fuel economy of inspected vehicles.
limit 2-stroke motorcycles	MC2	Base case assumes 40 percent of new registrations are 2-stroke motorcycles. The policy scenario assumes that only 10 percent are of this type. We use the OTA study for incremental cost ($100/unit) and for assumptions about fuel economy and emissions.
carbon tax		see text.
increase share of urban mass transit	BUS	In the base case we assume that the bus share falls from 90 percent to 85 percent by 2010. In the policy case we assume that the bus share is maintained at 90 percent.

Annex 1. Estimates of Fuel Economy by Vehicle Type

Table 8–7: Passenger Car Fuel Economy (miles per U.S. gallon)

country	source	engine size/make	litters/100km	miles/US gallon
Taiwan	(1)	600-1200cc		30.9
	(average	1201-1800cc		27.67
	1984)	1801-4200cc		22.23
Taiwan	(1)	600-1200cc		30.5
	pre-1977	1201-1800cc		25.1
	models	1801-4200cc		21.7
Taiwan	(1)	600-1200cc		30.9
	post-1980	1201-1800cc		27.6
	models	1801-4200cc		22.2
Taiwan	(2)	average,	8.5	27.8
Thailand	(4)	Bangkok, 1986		23.65
		non-Bangkok, 1986		26.02
Korea	(3)	average, 1983		23.37
		average, 1987		23.18
India	(2)	ambassador	13.6	17.4
Japan	(2)	Toyota Corolla	6	39.4
		Honda Civic	6.4	39.4
Germany	(2)	VW Rabbit	6	39.4
Sri Lanka	MEIP, USAID	assumed average		19

Sources:
(1) J. Sathaye and S. Meyers. 1987. "Transport and Home Energy Use in the Cities of the Developing Countries: A Review," *The Energy Journal*, 8: 85-103.
(2) Korea Energy Economics Institute (KEEI). 1989. "Sectoral Energy Demand in the Republic of Korea." Report to the ESCAP Regional Energy Development Program. Data are derived from the Korea Energy Census (1987 for year of 1986, and 1984 Census for the year of 1983).
(3) National Energy Administration. 1989. "Sectoral Energy Demand in Thailand." Report to ESCAP Regional Energy Development Program, p.55.

Table 8–8: Fuel economy of motorcycles

Country	Source		miles/ US gallon
Korea	(1) KEEI		90
unspecified	(2) OTA	2-stroke	50.0
		4-stroke	67.0
Thailand	(3) NEA	Bangkok	63.9
		non-Bangkok	75.7
Sri Lanka	(4)	2-stroke	49.0
	USAID/MEIP	4-stroke	37.7

Sources:
(1) Korea Energy Economics Institute (KEEI). 1989. "Sectoral Energy Demand in the Republic of Korea." Report to the ESCAP Regional Energy Development Program, p. 125; based on survey data.
(2) OTA, op.cit., p.
(3) National Energy Administration. 1989. "Sectoral Energy Demand in Thailand." Report to ESCAP Regional Energy Development Program, p.55.
(4) MEIP/USAID, op.cit; basis unclear.

nificant. In the case of the vehicle inspection and maintenance (I/M) program, for instance, they may range from the cost of importing the necessary emissions analysis equipment to the implied cost to owners whose vehicles fail inspection. If we make the assumption that the cost of repairs or extra maintenance to the vehicle owners are offset by fuel savings, there still remains the additional and administrative cost, for which we make the assumption of a US$10 cost per vehicle inspected per year. For some of the other measures, such as limiting the number of two stroke motorcycles, we use the Office of Technology Assessment (of the U.S. Congress) (OTA) estimate of incremental cost of US$100 per vehicle. Our transport sector scenarios are summarized on table 8–6. In addition to the two MEIP action plan measures, we also examine carbon taxes, and the impact of a shift in the share of passenger kilometers provided by mass transit.

The impact of carbon taxes is assumed to be captured by application of the applicable price elasticity to the real price increases that follow the imposition of such taxes. The econometric evidence of a price effect for gasoline is quite strong, with a short-run price elasticity of demand of -0.4 and a long-run elasticity of -1.05. For diesel, the effect is much less (about -0.1), and statistically barely significant. The econometric analysis is presented in Annex 2.

Annex 2. Econometric Analysis[48]

Selection of the appropriate model specifications for econometric estimation of price and income elasticity's is very much a matter of understanding the underlying trends in prices and demands. Figure 8–13 summarizes the important price trends during the past twenty years. Clearly the impact of the two world oil price shocks was quickly passed to the consumer. Since the early 1980s there has been a decline in the real price for both fuels. In 1989, however, the gasoline price was increased sharply, without a corresponding adjustment to the diesel price.

Indeed, the ratio of gasoline price to diesel price has gone through three distinct phases. Until the second oil price shock, this ratio was around 2.0 but was allowed to fall in 1981 to about 1.7, at which level it was maintained until 1988. With the rise in gasoline price starting in 1989, the ratio has climbed back to its level in the 1970s.

There appears to be an impact of the drop in price ratio for all three major vehicle categories: the higher the gasoline to diesel price ratio, the higher the ratio of new diesel registrations. There are clear lag effects, however, and initial purchase decision, especially for cars, is also a strong function of initial price, for which we have yet to collect appropriate time series.

In figure 8–14 we show gasoline consumption in the three major vehicle types together with the price of gasoline (as constant 1985 rupees per liter). Clearly the 1973 price shock significantly depressed gasoline demand in the subsequent years. The second price shock in the late 1970s had a much smaller effect, because it was to a large extent offset by a surge in economic growth that occurred in the same period immediately following the liberalization in 1978. During the 1980s the relative price drifted down, and gasoline consumption began to grow again. The sharp increase in gasoline price in the 1989–91 period apparently has had little impact on the growth of consumption, however. We know from the previous section that this period has also coincided with the rapid growth in motorcycle use.

Diesel consumption and price trends are illustrated in figure 8–15. The highest growth rate in consumption came in the postliberalization period, despite the fact that this was also a period in which the real consumer price of diesel almost tripled. Based on this data, with most of this growth occurring as a result of the increase in private buses, we would not expect to see much of a price effect. Indeed, during the 1980s, with the real price showing a steady decline, growth rate in diesel consumption slowed again.

Model for Gasoline Consumption

We begin with the widely used partial adjustment model[49]

$$Q_t = f(Q_{t-1}, P, Y)$$

where Q_t is the fuel consumption, P is price, and Y is income. The results were as follows:

Total gasoline consumption: partial adjustment model

$$\ln Q_t = \underset{}{0.16} + \underset{(0.124)}{1.362 \ln Q_{t-1}} - \underset{(0.105)}{0.618\, d(P_{gaso})} - \underset{(0.095)}{0.182\, dPR} + \underset{(.74)}{0.545 \ln d(GDP)}$$

sample period: 1973-90; R^2=0.92; figures in parentheses are standard error of estimate

where

Q_t gasoline consumption at time t
dPR ratio of gasoline to diesel price
$d(P_{gaso})$ change in the real gasoline price
$d(GDP)$ change in real GDP

Although the signs and magnitudes of the elasticities are consistent with expectations, theory holds that the lag coefficient for geometrically distributed lags assumed in the partial adjustment model is less than unity, as opposed to the actual result of 1.362. The generally unsatisfactory nature of all specifications we tried with gasoline consumption as the dependent variable is hardly surprising in light of the discussion of previous sections. Much better is the vehicle use lagged endogenous model, in which the dependent variable is gasoline consumption per vehicle.[50] This, clearly, will be a strong function of the fraction of motorcycles in the vehicle mix, and provided the following model:

Gasoline: vehicle use lagged endogenous model

$$\ln (G/V)_t = 1.94 + \underset{(0.068)}{0.708 \ln(G/V)_{t-1}} - \underset{(0.094)}{0.334\, d(P_{gaso})} - \underset{(0.036)}{0.17 f(mc)} + \underset{(.07)}{1.46 \ln d(GDP)}$$

sample period: 1973-90; R^2=0.99; figures in parentheses are standard error of estimate

where

$(G/V)_t$ = gasoline consumption per vehicle at time t

$d(P_{gaso})$ = change in the real gasoline price

$d(GDP)$ = change in real GDP

$f(mc)$ = fraction of motorcycles

This is a much more satisfactory model, with results consistent with the theoretical hypothesis. The long-run price elasticity is

$$0.334/(1. - 0.708) = 1.14,$$

which is remarkably close to the -1.05 average of all studies, mostly in developed countries, reported by Dahl and Sterner 1991. The income elasticity, however, is much higher (1.44 as opposed to the reported average of 0.14): but that is also as expected for a low-income country like Sri Lanka.

A variety of functional specifications has been suggested in the literature for modeling automobile ownership. Most studies have used the traditional constant elasticity model of the log linear form. One recent study (Button, Ngoe, and Hine 1993) argues, however, for the use of a quasi logistic specification, which includes the number of vehicles per capita, the postulated saturation level, and a number of conventional explanatory variables (such as price and GDP).

When we examine the results of this study for the group of low-income countries that included Sri Lanka, for which a saturation value of S = 0.35 was assumed, however, there is very little difference between the income elasticity in the log linear specification (0.73) and the quasi logistic (0.70). Given even a 1990 level of car ownership in Sri Lanka of 0.0056 per capita, two orders of magnitude lower than the saturation level,[51] that is hardly surprising, given the difference between actual number of cars and presumed saturation level.

In any case, models for vehicle ownership were generally unsatisfactory, perhaps in part because we did not have data for the price of automobiles. The price of gasoline can be expected to have a lesser influence than the initial price of the vehicle itself,[52] and gasoline price was not statistically significant.[53] The best model for passenger car ownership, given the time series that were available, was as follows:

Passenger car lagged endogenous model

$$\ln V_t = 1.943 \; + \underset{(0.047)}{0.907 \ln V_{t-1}} \quad \underset{(.79)}{0.61 \ln d(GDP)}$$

sample period: 1979-90; R^2=0.978; figures in parentheses are standard error of estimate

where

V_t = number of passenger automobiles at time t (includes both diesel and gasoline vehicles)

$d(GDP)$ = change in real GDP

The GDP variable has the right sign, and is about of the expected magnitude,[54] but is not statistically significant. Use of vehicles per capita, GDP per capita, or population growth as variables provided no improvement. We simply excluded the years in which import controls were imposed on automobiles prior to 1978; use of a dummy variable proved unsuccessfu. We are currently collecting additional data to derive a consumer vehicle price index.

A Model for Diesel Consumption

Neither price nor GDP variables explained total consumption of diesel, which is not surprising in light of the many different trends that occurred during the last decades. The most successful, or the least unsuccessful, was again a vehicle use lagged endogenous model, which gave the following results:

Diesel: vehicle use lagged endogenous model

$$\ln(D/V)_t = 1.466 + 0.259 \ln(D/V)_{t-1} - 0.106\, d(P_{autod}) - 0.71\, f(light) + 0.45 \ln d(GDP)$$

$$(0.242) \qquad (0.049) \qquad (.26) \qquad (.47)$$

sample period: 1978-90; $R^2=0.99$; figures in parentheses are standard error of estimate

where

$(D/V)_t$ = diesel consumption per vehicle at time t

$d(P_{diesel})$ = change in the real diesel price

$d(GDP)$ = change in real GDP

$f(light)$ = fraction of light diesel vehicles in the fleet

Price and income elasticities have the expected sign, and are of about the expected size; but the time series had to be shortened to exclude the initial years of import controls. As might be expected, the price elasticity for diesel (-0.1) is significantly less than that observed for gasoline.

A variety of models was tried for prediction of the number of diesel vehicles, or new registration rates, but none proved statistically significant.

Conclusions

That these preliminary econometric analyses proved generally disappointing is hardly surprising, given that the eighteen year time period for which data was available was characterized by so many exogenous factors that make statistical estimation difficult. The period of import controls, the growth surge of the late 1980s which coincided with the second oil price shock, the various disruptions due to civil disturbances, the rapid growth of the Colombo metropolitan area, the decontrol of passenger bus service—so many forces were acting upon the road traffic situation that isolation of individual factors is inevitably very difficult, given the shortcomings of the data.

In the next stage of this study we shall attempt to redress some of the data short-

Table 8–9: CEB Estimates of the LRMC

	LRMC Rs/kwh	losses, as % of generation	percentage of total demand
generation	2.21	1.9%	
HT transmission		3.9%	
HV	2.63		
grid substation		1.8%	
HV2	2.75		0.94%
transmission		4.8%	
MV3	4.23		11.56%
substation		1.3%	
MV2	5.28		48.75%
distribution		3.5%	
LV	5.7		38.75%

comings—by lengthening the time series, and collecting additional data on key variables, such as purchase price of vehicles.

Nevertheless, there is strong evidence for a price effect for gasoline: and the estimated short and long run elasticities (-0.4 and -1.1, respectively) are consistent with values encountered elsewhere in the literature. As we might expect, there is less evidence of a price effect for diesel fuel.

The Environmental Impacts of Electricity Pricing Reform

As noted in the introduction, the rationale for, and importance of, economically efficient pricing is well established, and has been documented in many studies. Historically, Sri Lanka has followed the same cyclical pattern observed in many other developing countries. This pattern is characterized by long periods during which the government is reluctant to raise tariffs, which results in a gradual deterioration of the financial condition of the utility, and is in turn followed by sharp increases necessary to ward off a crisis. Thus, for example, between 1972 and 1978 there were no changes in the tariff, resulting in a gradual decline in real electricity price level. This was followed by a series of very sharp rate increases in the period 1978-80 (see figure 8–16). Prices drifted downward again in the early 1980s, with a correction in 1988. They drifted downwards again until 1992, when a further series of significant tariff increases occurred.

The failure to maintain a consistent pricing policy has a number of possible environmental impacts, in addition to the expected and obvious impact upon the financial condition of the utility.[55] When tariffs are substantially below long-run marginal cost (LRMC), it becomes difficult to raise the resources necessary to expand and upgrade the T&D system, resulting in turn in high loss rates characteristic of over stressed systems. This is compounded by wasteful consumption—and hence also higher levels of generation—where price levels are significantly below their economic level. The result is that the environmental impacts associated with electricity generation are higher than they would be in an efficient system. With the new projects becoming increasingly controversial—hydro projects because of the impacts associated with inundation, and fossil fueled projects because of impacts associated with air pollution, solid waste disposal, and thermal effluents — eliminating those environmental impacts associated with inefficiency becomes increasingly important.

In this section we seek to quantify the relationship between pricing policy and environmental impacts. This is done by simulating the expansion of the electricity system under various assumptions about pricing policy, and quantifying and comparing the resulting environmental impacts at the systemwide level.

Electricity Prices and LRMC

Electricity prices in Sri Lanka have historically been at levels substantially below long-run marginal cost (LRMC) (see Munasinghe and Warford 1982). In 1992 a series of tariff increases raised the average price to 2.6 rupees per kilowatt hour. Even this price level is below the latest estimate of the CEB, however (Table 8–9)[56].

It thus comes as no surprise that the financial performance has been below target levels of return on assets or equity as well. Prior to 1984, however, when the fuel adjustment clause was invoked,[57] financial performance was subject to sharp deterioration during periods of drought as a consequence of heavy use of thermal plants dependent upon imported fuels. As indicated in Figure 8–17, the drought year 1983 resulted in heavy financial losses as a result. Nevertheless, since 1983 the real price has drifted downward, as has the return on equity from a post drought peak of 4 percent in 1985 to less than 1 percent in 1991. These returns are substantially below normal target levels of 5 to 10 percent.

Econometric Analysis

Is electricity demand in Sri Lanka in fact price elastic? Some load forecasting models used by the CEB do not in fact include a price variable.[58] As shown in Annex 3, simple econometric models do not show any statistically significant evidence of demand elasticity. Indeed, in order to derive a satisfactory econometric model, it becomes necessary to first examine the underlying structure of electricity demand.

Figure 8–18 shows electricity demand and real GDP growth. Over the past two decades, demand growth has averaged 7 percent per year. Real GDP growth experienced a sharp upturn in 1978 with the liberalization of the economy started by the incoming Jayawardena administration; but civil disturbances in the late 1980s caused a decline in both economic growth and in the growth rate of electricity demand, which was negative in 1989.

Figure 8–19 portrays perhaps the most important underlying trend—the fall in kilowatt hour per customer account. For the industrial sector, this is a sharp and consistent trend, indicative of long term structural adjustments in the industrial sector, with many small medium- to small-sized light manufacturing enterprises taking the place of large state owned facilities as the dominant consumers.

The trend is observed also in the household sector, with a consistent decrease from the peak consumption of 1.2 megawatt hours per account per year in 1983 to 0.9 megawatt hours per account per year in 1991. For commercial accounts there is no discernible trend during the period 1987-88, but there was a sudden fall in the period 1988-91. This corresponds precisely with the onset of significant civil disturbances, during which shopping hours were dramatically curtailed in the evening. It remains to be seen (once the 1992 data are compiled) whether shopping habits and store hours have returned to previous patterns now that normal conditions prevail in most of the country. We might note that these declines in consumption per connection are not obviously related to price, since in the period 1988-91 real prices decreased.

A further significant distortion of the aggregate data has occurred as a result of the gradual takeover of local municipalities by the CEB and by the Lanka Electricity Company (LECO). LECO is a private sector distribution company established in 1983 to take over some of the more egregiously run municipal authorities on the perimeter of Colombo, some of which had loss rates of more than 40 percent at the time of takeover![59] The significant progress made by LECO in reducing losses in its system is another factor in decreasing consumption per consumer (all other things being equal, its wholesale purchases from CEB will be less, the lower the T&D loss rate).[60]

In sum, it is inevitable that the combination of special circumstances that has prevailed since the mid 1980s will make econometric analysis more difficult. Structural changes in manufacturing, takeover of municipal systems, civil disturbances, and severe droughts in 1983 and 1987 that resulted in significant curtailments all combine to make this an unusual period.

The details of the econometric analysis are presented in Annex 3. As soon as the model is properly specified, with due recognition of the impact of structural changes in customer demand, statistically significant price elasticities can be identified. Estimated values lie in the range of -0.07 to -0.5. Only for the industrial sector was the estimated value (-0.07) not statistically significant.

Pricing Scenarios

To examine the impacts of alternative pricing policies, we define a series of pricing scenarios. A first case, obviously, is what might be termed business as usual, in which we set the tariff in such a way as to maintain the historical average of 3 percent return on equity. This has a rather small chance of realization, for it generates insufficient cash to also maintain satisfactory self financing ratios.

Table 8–10: The Impact of Pricing Policy

	3% return	meet all covenants	AIC
PV(capital investment),US$ m	1,214	1,159	963
levelized tariff, Rs/kwh	2.82	3.46	5.17
impacts in year 2005:			
fuel imports, $USmillion	73	64	51
installed capacity, Mw	2,170	2,130	2,050
CO_2 emissions, mt/year	4.07	3.63	3.03
demand, gwh	7,638	7,197	6,624
tariff, Rs/kwh	3.1	4.2	6.2

Consequently we define a second base case tariff policy based upon a postulated covenant that requires an 8 percent rate of return on equity. This reflects typical World Bank practice for power sector lending, and, implies a substantially higher rate of return than has been achieved at any time during the past twenty years.

An iterative adjustment algorithm is used in the model to identify the average tariff level required in each year to maintain the required balance sheet ratio. Because of the lumpiness of capital investment, the year to year level of the tariff may show considerable variation, which would not only be hard to implement but would likely send confusing signals to consumers as well. The assumption here is that an appropriate smoothing process would be applied at the stage of policy implementation.

A further option is to base the tariff on the long-run marginal cost (LRMC). When the LRMC at each voltage level is weighted by the fraction of demand delivered at that level, an average LRMC of 5.29 rupees per kilowatt hour results, implying that the incremental marginal cost of transmission and distribution is 3.68 rupees per kilowatt hour.[61]

ENVIROPLAN calculates average incremental costs (AIC), which is also a measure used by the CEB generation planning branch to compare system expansion alternatives in its annual generation plan.[62] The AIC of generation proves to be a good proxy for LRMC at the generation bus: our base case values of generation AIC lie in the range of 2.15 to2.38 rupees per kilowatt hour, depending upon fuel price and capital cost assumptions, very close to the rigorously estimated LRMC of 2.21 rupees per kilowatt hour (all in 1992 rupees). To obtain the total estimated LRMC to the consumer, used in turn as the level of the average tariff in the financial statements and the demand forecasting equation,[63] we add 3.68 rupees per kilowatt hour (that is, that component of LRMC attributable to T&D) to the generation AIC.

With the current tariff on the order of 2.6 rupees per kilowatt hour, and the AIC in the range of six rupees per kilowatt hour, such an LRMC-based tariff would require a phase in period. We assume a five year period, such that the 1994 tariff would be at least at 20 percent of the LRMC, the 1995 at 40 percent, and so on, with the tariff at the full level of the LRMC by 1998.

Table 8–10 shows the impact of these different pricing policy scenarios on some key indicators. Even to meet all the existing covenants, the tariff needs to be raised to more than four rupees per kilowatt hour. In fact, of the three covenants now in place, it is the current ratio that proves to be binding for most of the next decade (see figure 8–20).

Figure 8–21 shows the impact of pricing policy reform on three environmental indicators: GHG emissions, local health impacts due to fossil fuel combustion,[64] and biodiversity impact.[65] These results are displayed in terms of the system cost variable, for which we use the present value of total electric system costs, and the discounted value of the environmental variable over the same planning horizon, and at the same discount rate (10 percent). As discussed in Meier and Munasinghe 1993, the results are robust with respect to a wide range of discounting assumptions for the physical flows, including the use of undiscounted GHG-emissions (that is, zero discount rate).

As expected, moving from business as usual (3 percent return on equity) to 8 percent return, and then further to an LRMC-based tariff, reduces both system costs, and all three of the environmental impact measures.

In fact the conclusions are remarkably robust with respect to a range of uncertainties. The sensitivity analysis results displayed in Figures 8–22 and 8–23 indicate the benefits of pricing policy reform over wide ranges of assumptions about economic growth rates (or income elasticity of electricity demand), world energy prices,[66] construction delays[67] and the price elasticity of demand. Indeed, the main conclusion can be stated quite unequivocally. Although the magnitude of the environmental benefit may be debatable because of uncertainties concerning the price elasticity effect, at worst (that is, in the case of no price effect) we can be certain that there is no negative effect upon the environment.

Table 8–11: Standard Model, Total Electricity Consumption

$ln\ dE_t =$	1.01	$+ 0.035\ ln\ d(P_{elec})$	$+ 1.342\ ln\ d(GDP)$
		(0.03)	(.53)
	sample period: 1972-1991; R^2=0.357; figures in parentheses are standard error of estimate		
where	dE	change in electricity consumption	
	$d(P_{elec})$	change in the real electricity price	
	$d(GDP)$	change in real GDP	

Table 8–12: Autoregressive Model, Consumption per Customer

$$\ln [Q/N]_{t-1} = 1.01 + 1.970 \ln([Q/N]_{t-1}) - 0.09 \ln d(P_{elec})$$
$$\qquad (0.008) \qquad (.07)$$

sample period: 1973-1991; R^2=0.963; figures in parentheses are standard error of estimate

where $d(P_{elec})$ change in the real electricity price

$[Q/N]_t$ consumption per account

Table 8–13: Autoregressive Model, Consumption per Customer, 1973-82

$$\ln [Q/N]_{t-1} = 1.62 + 0.754 \ln([Q/N]_{t-1}) - 0.237 \ln d(P_{elec})$$
$$\qquad (0.15) \qquad (.10)$$

sample period: 1973-1991; R^2=0.897; figures in parentheses are standard error of estimate

where $d(P_{elec})$ change in the real electricity price

$[Q/N]_t$ consumption per account

Conclusions

Setting electricity prices to reflect the LRMC has a significant, and unambiguously beneficial, impact on the environment, both in country and globally. The expected benefits predicted on theoretical and intuitive grounds are in fact confirmed by the specific case examined. For example, the difference between an AIC-based tariff and one based merely on achievement of a financial covenant to assure a 10 percent rate of return is a 6 percent reduction of greenhouse gas emissions in 2010, and a 10 percent reduction in adverse health effects related to the exposure of human populations to the incremental ambient concentration of air pollutants.

It is true that the environmental benefits that follow from pricing reform are dependent upon assumptions about the price elasticity of demand. Even under the unlikely assumption of zero price elasticity, however, we can be sure that the environmental impact of pricing reform is not negative.

The emphasis given to efficient pricing in both project loans and adjustment lending is therefore justified not only on grounds of economic efficiency, but also on grounds of minimizing the environmental damages of economic development.

Annex 3. Estimation of Electricity Price Elasticities

We begin the econometric analysis with the standard logarithmic specification with constant elasticities

$$\boxed{\ln dE = a + b.\ln d(P_{elec}) + \ln d(GDP)}$$

where
dE = change in electricity consumption
$d(P_{elec})$ = change in the real electricity price
$d(GDP)$ = change in real GDP.

The results are shown on table 8–11.

These results are quite unsatisfactory: the price coefficient has the wrong sign, and overall R^2 is low. Based on the above discussion of the underlying trends, and on the findings of other surveys, the model specification is inappropriate. Clearly, with significant shifts in consumption per account, and the number of accounts particularly in rural areas subject to policies that have no linkage with economic or price variables, we need to identify a more appropriate specification.

Table 8–12 shows a first step in this search. We use an autoregressive form consistent with the hypothesis of dynamic adjustment, and use consumption per account as the dependent variable.[68] Addition of an income variable to this form was clearly statistically insignificant, and had no effect on the magnitude of the estimated price coefficient.

Indeed, the results of this formulation are predictably better. R^2 increases to .93, and the price coefficient has the expected sign. The standard error for the price elasticity is high, however. When we examine just the normal years by excluding the years from 1983 to 1991 during which there were significant civil disturbances, and several severe droughts, we obtain the results indicated on table 8–13.

The price elasticity is now -0.23, and the significance of the price coefficient has improved, although the overall R_2 falls slightly to 0.897. The coefficient for the autore-gressive term is now also less than unity, however, and consistent with the distributed lag hypothesis. This permits the estimation of the long run price elasticity as

$$\beta_L = \frac{\beta}{1-\lambda}$$

where

$$\beta_L$$

is the long-run elasticity,

$$\lambda$$

is the autoregressive coefficient, and

$$\beta$$

is the short run coefficient: hence

$$\beta_L = \frac{0.237}{1-0.754} = 0.963$$

We examined a variety of other specifications involving sectoral data, and data just for certain regions. The estimated price coefficients were as shown on table 8–14. All are for autoregressive logarithmic specifications.

In summary, we note that the results are significantly affected by the model specification and the time period selected. Clearly there are fundamental underlying structural changes at work that have significantly reduced the consumption per customer, whose impact is still greater than

Table 8–14: Sectoral and Regional Estimates: Long Run Price Elasticity

sector	region	estimate
all	Colombo	-0.29
industry	all	-0.07 (not significant)
residential	all	-0.14
commercial	all	-0.5

(1) all are estimated in dynamic adjustment models.

Table 8–15: Fossil Energy Carbon Emissions, 1986 (1)

Country	1986 emissions million tons carbon	Tons carbon/capita	Tons carbon/ US$ 1,000 GNP
China	548	0.5	1.7
India	119	0.2	1.5
Indonesia	27	0.2	0.4
Thailand	12	0.1	0.3
USA	1,418	4.9	0.3
Japan	268	2	0.1
U.K.	161	2.9	0.2
Sri Lanka	0.9	0.06	0.13

(1) Sri Lanka estimates by authors, others from Baron and Hills (1990).

the increase in per consumer consumption expected as a result of income increases. When properly specified, however, there is clear evidence of a price effect, for which a value of -0.2 seems reasonable to use in our simulation model as the base case.[69] We deal with the uncertainty in the magnitude of this coefficient by appropriate sensitivity analyses.

Greenhouse Gas Emission Reduction Options

Carbon emissions in Sri Lanka, both in absolute terms as well as in per capita terms, are presently still extremely low (see table 8–15), a reflection of the dominance of hydro in the electric sector, and low energy intensity of the industrial sector. Beyond the year 2000, however, carbon dioxide emissions will rise very sharply as the electric sector generation mix moves toward fossil fuel, as indicated in figure 8–24. This has important consequences for the negotiating posture of Sri Lanka in the event that a consensus emerges for tradable carbon dioxide emission rights; clearly it will be in the interests of small developing countries whose present electric systems are hydro dominated to argue that the initial allocation of emission rights be based on population, or income, rather than on present fossil fuel consumption.

Indeed, Sri Lanka may be an example of a country that is as much affected by the global measures to reduce carbon dioxide emissions, as by the physical impacts of any global warming that may in fact occur. Some of the recent studies of measures that might be necessary to stabilize carbon dioxide emissions have staggering implications for developed and developing countries alike. At a recent ESCAP conference (Jones and Wheeler 1992), several studies indicated carbon taxes on the order of US$50 to US$300 per ton might be necessary. Ogawa and Awata (1991) estimated that if carbon dioxide were to be stabilized by a single worldwide carbon tax, by 2000 the requisite tax level would be US$90 per ton (in 1985 U.S. dollars), increasing to US$288 per ton by 2025. If the tax were levied only on the OECD countries, the year 2000 tax would need to be US$185 per ton, two times higher than in the worldwide version[70]. Coppel (1991) presented the results of an International Energy Agency (IEA) study indicating carbon taxes of US$100 per ton might be necessary, in combination with a "50 percent nuclear policy"[71] to bring a 20 percent reduction in OECD carbon dioxide emissions by 2005.

Such tax levels are perhaps not very likely to materialize. Yet much more modest rates of carbon tax, even if imposed only in the industrialized countries, will have substantial implications for relative fuel prices, and the ratio of coal to oil prices in particular has relevance for fossil fuel importing countries such as Sri Lanka.

Nevertheless, even if it is true that reasonable levels of carbon taxes will not stabilize carbon dioxide emissions in developing countries to anywhere near their present levels, it is still true that even small rates of tax may be an effective instrument to reduce carbon dioxide emissions to below what they might otherwise be. If the industrialized countries are to be expected to bear the brunt of carbon dioxide emissions reductions, then the political symbolism of developing countries adopting at least some reasonable policy measures themselves may be of great importance.

On the other hand, the impacts of global warming that might be experienced by Sri Lanka are also quite uncertain. Some researchers expect an intensification of the monsoon in tropical latitudes, which may adversely affect soil erosion and stability in the hill country watersheds where deforestation already makes more likely an increase in the sediment loads that will affect both hydro and irrigation reservoirs. Unlike many other countries in Southeast Asia, the tectonic conditions in Sri Lanka are relatively stable, with little significant seismic activity of the type that has produced significant surface depressions of coastal areas in the Philippines.[72] Nor are the major cities presently threatened by major subsidence problems caused by excessive exploitation of groundwater.[73] Nevertheless, extensive areas of the coast, especially in the south and southwest, are already threatened by coastal erosion,[74] and there are extensive areas of highly populated coastal areas that would be severely affected by sea level rises of one to three meters. One of the immediate consequences of sea level rise is likely to be contamination of the limestone aquifers that are important sources of groundwater in the north.[75]

The future course of GHG emissions in Sri Lanka itself will be largely determined by policy and investment choices in three main areas. First is the generation mix in the electric sector—clearly, the extent to which coal is used as a major fuel, and to which the remaining hydro resources can be exploited, will have a major impact on carbon dioxide emissions. Second is the rapidly growing transportation sector, which accounts for about half of the petroleum product consumption. Second is the traditional fuels sector. As noted earlier in this chapter, biomass still accounts for two thirds of energy consumption in Sri Lanka, and any major shift from biomass to petroleum based fuels for household cooking would have a major impact on carbon dioxide emissions. In this section we analyze in detail the first two of these areas.

Analyzing GHG Emission Reduction Options Using Multi Criteria Analysis

Multi-criteria analysis (MCA) as a tool for analyzing tradeoffs between economic and environmental objectives in power system planning was first applied to Sri Lanka in an earlier study (Meier and Munasinghe 1994), to which the reader is referred for detailed discussion.

Tradeoff curves are a particularly useful tool in such analyses. Figure 8–25 illustrates the essential concepts. The figure is a plot of two attributes—GHG emissions and total system costs—for the technology options identified presented earlier in this chapter (see table 8–2). Each point represents a perturbation of the reference case, which is defined as the official 1993 base case capacity expansion plan of the CEB.

The tradeoff curve is the set of options that are not dominated by others, and are sometimes referred to as the non-inferior set. These are the options that are closest to the origin, and therefore represent the best set of options that merit further attention.[76]

The concept of dominance is illustrated in figure 8–25.[77] PFBC (a clean coal technology. See above and figure 8–6) is said to dominate the options in the sector shown in figure 8–25, which are FGD (in which coal plants are fitted with flue gas desulfurization systems); wind; and *FGD.[78] PFBC has better (that is, lower) costs and better (that is, lower) GHG emissions, and is thus preferred over these options under both criteria. If only these two attributes mattered, then there would be no reason to select any of the dominated options in place of PFBC.

Another perspective is gained by dividing the solution space into the quadrants with respect to the reference case (figure 8–26). The most desirable options naturally fall into quadrant III, where both costs and GHG emissions decrease. These are the win-win (or no regrets) options, which are better than the reference case in both attributes. In this case, mini-hydro, energy efficient refrigerators, T&D system loss reduction and compact fluorescents all fall into this quadrant, providing both cost and emission gains. The options in quadrant I, on the other hand, are those for which costs and GHG emissions increase over the base case—which might be termed lose-lose!

It is of course a reasonable question why the measures that appear in quadrant III, such as the DSM measures, and mini-hydros, are not part of the base case, given that they would decrease overall system costs, and that they should therefore be part of even a narrowly defined least-cost solution.[79] For the purposes of this study, however, we considered it important for our base case to be equivalent to the official CEB base case expansion plan.

The options in quadrant II have lower system costs, but higher GHG emissions, while in quadrant IV, system costs increase, and GHG emissions decrease. In other words, these are the quadrants for which tradeoffs between the cost and GHG-emission objectives must be made.[80]

There are several different ways in which GHG emission attribute might be defined:

- As cumulative GHG emissions over some planning horizon — for instance, from the present to 2011, as in this study. This is equivalent to a zero discount rate for GHG emissions
- As emissions in a particular year, for instance, in the last year of the planning horizon (or 2011)
- As some discounted measure of GHG emissions over time (for instance, at the same rate as the discount rate for financial flows).

This is a much debated topic. We here take the view that the third option is the appropriate approach for a study of this type. The reasons are as follows:

- The use of a zero discount rate implies a threshold effect that no impacts will occur during the planning horizon considered: a ton of carbon dioxide emitted in year one is equivalent to a ton emitted in 2011. If there is no threshold effect, however, then the timing of GHG emissions is clearly of concern. In any event, there is much uncertainty as to the persistence of GHGs in the atmosphere.
- If in fact emissions of GHGs over the planning horizon are all treated equivalently, then there is incentive to delay decisions to reduce GHGs because

Table 8–16: Cost of Avoided Carbon Emissions (U.S. dollars per ton)

	undiscounted	discounted (at 10%)
wind	67	159
maximum hydro	64	150
no coal	16	35

*as change in 1993 present value of system cost per ton of carbon avoided over the planning horizon 1993-2011.

—if financial flows are discounted, and GHGs emissions are not, the option to delay action will always appear to be preferred over taking an equivalent action today.

As illustrated in Annex 5, however, if we hold fixed the discount rate applied to financial flows, then the tradeoff curves are much the same for these three different definitions for the GHG attribute — the options that lie on the tradeoff curve are generally the same , and the shape of the curves do not differ greatly. the definition of the GHG emissions attribute certainly does make a significant difference to calculations of the cost per ton of carbon emission avoided, however, as illustrated in table 8–16.

Some of the results require detailed explanation, because at first glance they appear counter intuitive. Two solution options are shown for flue gas desulfurization, identified as FGD, and as *FGD. The first, FGD, allows the model to optimize the system, provided coal plants are fitted with FGD systems. Figure 8–26 suggests that this option provides significant carbon dioxide reduction benefits. Inspection of the solution shows that this is because the model prefers to build diesels rather than coal plants with FGD systems—with the result that by 2011 only 300 megawatts (MW) of coal, rather than 1,000 MW as in the base case, are built. Hence the reduction in GHG emissions.

The second option, identified as *FGD, simply adds FGD systems to any coal plants that are in the base case. This option also provides GHG emission reductions (but is dominated by FGD!). Thisproves to be a consequence of rate feedback, however. Because FGD systems significantly increase costs, in order to meet the same return on equity criterion tariff must increase, which in turn depresses demand. In the absence of rate feedback, GHG emissions increase as a result of the use FGD systems. Because of the energy penalty of FGD systems themselves, about 5 percent of station output, all other things being equal more coal must be burnt, and hence more carbon dioxide will be released per kilowatt hour of net (that is, after station use) generation.[81]

Table 8–17: Capital Cost and Performance Assumptions for Coal Technologies

	capital cost US$/kw	heat rate KCal/kwh
base case (pulverized coal,no FGD)	1,350	2,560
PC with FGD	1,553	2,631
PFBC	1,450	2,326
PFBC-	1,620	2,326

There are also two options shown for PFBC: labeled PFBC, and PFBC, with the latter case using more pessimistic assumptions about capital costs (see table 8–17). PFBC appears to provide greater reductions in GHG emissions than PFBC. Inspection of the solution shows that in the pessimistic cost case, PFBC plants are not built at all, and the benefits of GHG reduction occur from substitution by diesels rather than from the PFBC technology itself. On the other hand the scenario marked PFBC, in which the capital cost is more optimistic, does indeed provide GHG reduction benefits—although at a much more modest level—from application of the technology itself.

Based on these results several conclusions follow:

- Wind and hydro plants are expensive ways of reducing carbon emissions, and can only be justified as the last step of a GHG emissions reduction program, after all coal plants have been replaced by diesels. As noted in Annex 4, however, an additional benefit of wind power is to increase system reliability, although the maximum hydro scenarios decrease reliability, or still further increase costs if reliability is held constant.
- None of the measures listed in table 8–16, however—all measures in quadrant IV of

Figure 8–26—are justified as measures to control GHG emissions unless all of the measures in quadrant III have been implemented first. In other words, implementation of DSM, T&D loss reduction to at least 10 percent, and mini-hydros are the priority measures from the perspective of GHG emission reduction. These measures also increase economic efficiency, and therefore do not, in theory, qualify for GEF funding (because, at least in principle, GEF will fund only incremental costs).

Do these conclusions change when we examine other environmental attributes? Clearly the calculations of table 8–16 in terms of U.S. dollar per ton of avoided GHG emissions ignore the other environmental costs and benefits that arise from the indicated options. Wind energy will reduce not just GHG emissions, but will reduce all emissions associated with the fossil fuel combustion it displaces. On the other hand, the no coal scenario, while it achieves significant reductions of GHG emissions, may not reduce other air pollutants. And the maximum hydro scenario significantly increases those impacts associated with inundation of large reservoirs. In other words, a strategy for GHG reduction must necessarily consider not just costs, but other environmental attributes as well.

In figure 8–27 we examine the tradeoff curve for sulfur dioxide emissions. Compact fluorescent lighting (CFL) and PFBC are still on the tradeoff curve, but are now joined by the options that involve the use of low sulfur fuels—identified as lowScoal, and lowSoil. As we might expect, these options provide significant reductions in SOx emissions at higher cost than the base case. *FGD systems which replaces the no coal and maximum hydro options that were on the carbon dioxide tradeoff curve.

Note that neither FGD, nor *FGD, lie on the tradeoff curve! The implication is that if coal plants must be fitted with FGD systems, then perhaps (and certainly this is the case in Sri Lanka), it is cheaper not to build coal plants at all—particularly if the costs of the new clean coal technologies prove to be higher than expected.[82] Note that PFBC—the pessimistic cost case for PFBC—does not lie on this tradeoff curve.

A further point of note is the location of the no coal case, in which the model builds significant numbers of diesels running on high sulfur oil. When 1 percent sulfur coal, and 3.5 percent sulfur imported fuel oil, are adjusted for heat content of the fuel and power plant efficiency, the net result is that more sulfur dioxide is emitted from diesels than from coal.[83]

Health Impacts

These arguments are even more apparent when we examine health impacts (rather than just emissions). As indicated in Figure 8–28, energy efficient refrigerators (EEF), mini-hydro and CFL are clearly on the tradeoff curve, together with lowSoil and PFBC. The 'noCoal+lowSoil,' and 'MaxHy+noCoal+LowSoil' do provide comparable reductions in health impacts, but only at very high cost.

The Impact of Location

In Sri Lanka, diesels and additional hydros are preferred to coal with FGD. As noted earlier, forcing FGD systems increases costs. On the other hand, if FGD systems are avoided, this turns out to increase sulfur dioxide emissions, because, at least in the base case, diesels are assumed to burn high sulfur fuel oil with as much as 3.5 percent sulfur by weight. The way out of this dilemma, obviously, is to use a clean coal technology such as PFBC, which reduces both sulfur dioxide and CHG emissions!

All of this follows largely from the location of plants. Coal plants tend to be built in relatively remote areas, and with tall stacks, such that ground level increments of pollutants in densely populated areas are quite small. Diesels, on the other hand, typically get sited closer to or, in the case of Sapugaskanda, almost in urban areas.[84]

Stacks are typically quite low, with the result that smaller numbers of people get exposed to significantly higher concentrations in the absence of remedial measures.

In any event, what this analysis shows very clearly is the desirability of making decisions about whether or not FGD systems are to be required on a systemwide basis, at the planning stage, rather than on a case by case basis at the project level, at the stage of the project environmental assessment.

The importance of location is illustrated even more dramatically in figure 8–29, which shows the time trends in the health impact index values for six options: the base case, CFL, wind, AIC, no coal, and 'maxHy+noCoal+LowSoil.' In all cases but noCoal, there is a general decline in health impacts in the 2000-05 period: this is when remote coal plants are assumed built, and the thermal plants closer to the urban centers get dispatched less. Thereafter, there is again an increase, as more and more coal enters the system (or, in the case of the maximum hydro+no Coal, more and more diesels). The importance of an appropriate siting and fuel quality policy is clearly evident.

Global Compared With Local Impacts

What is the correspondence between different environmental interests? Are solutions desirable from the perspective of a global environmental objective, namely GHG emission reductions, also desirable from a local environmental perspective? Very clearly, the maximum hydro scenarios, which force into solution all of the remaining major hydro plants in the interests of maximum GHG-emission reductions, are very undesirable from a local land use and biodiversity perspective. For example, the Kukule high dam variant, which would require displacement of some 9,000 people, also would inundate some forest land of high biodiversity value.

In figure 8–30 we examine the tradeoff between GHG emissions and the local environmental objective of minimizing the health impacts of power sector air pollutant emissions. For this purpose we have defined a health impact index, in which a Gaussian dispersion air quality model was applied to prospective power plant locations, and the resulting increments in ambient air quality for fine particulates and NOx overlaid with population distribution. Although we do not go one step further and apply mortality or morbidity functions, the use of population weighted ambient air quality changes is distinctly preferable to the use of just emissions as a measure of actual impact.

The tradeoff curve, as expected, indicates that there is no conflict between these two objectives. GHG emission reductions do not therefore come at the expense of an increase in local health impacts. The third dimension, incremental system cost, is indicated by each solution point (for example, PFBC lowers costs by US$16 million, whereas maximum hydro+no coal+wind increases costs by US$489 million). The potential attractiveness of PFBC-combined cycle, and other clean coal technology, becomes immediately apparent: with emissions reduced across the board from NOx to sulfur dioxide to GHG emissions, and high efficiency, this represents another potential win-win option that merits close attention. Thus, by looking at other environmental attributes as well, we can add to the previous conclusions the following:

- The no coal option for reducing GHG emissions requires a compensatory policy to reduce sulfur dioxide emissions by lowering the sulfur content of the residual oil burnt at diesel plants, in conjunction with an appropriate siting policy.
- PFBC, and very likely other new clean coal technologies, significantly dominate FGD for every attribute examined, including sulfur dioxide, GHG, and health impacts. This is not, of course, an unexpected result, given the inherent emissions performance of the technology. It

once again illustrates the point that FGD systems are a particularly poor approach to pollution control, however. Moreover, the results indicate very clearly the need to avoid making decisions about whether or not FGD systems are needed at the project-level environmental assessment stage. If FGD systems are in fact added at this stage, then we would be far better off not building a coal plant in the first place. In other words, there is no substitute for environmental benefit cost analysis at the planning and policy stage.

- The combination of no coal with low sulfur fuel oil and a siting strategy that avoids urban areas for diesels is to be preferred over the maximum hydro scenario, which incurs significant relocation and biodiversity impacts as the price for reduced GHG emissions.
- With the exception of large storage hydro plants, there is no conflict between a GHG control strategy and local environmental impacts. All of the measures in quadrant III (DSM, mini-hydro, and so on), as well as the 'no coal+lowSoil' and wind options in quadrant IV, also reduce the potential for local health impacts, and any impacts associated with coal solid waste disposal.

Comparison with Other Studies

How do our results compare with other studies? A recent study by London Economics (GEF 1992) for the GEF compiled a range of cost estimates for various power sector technologies relative to large coal plants.[85] Those relevant to Sri Lanka, and our results, are shown in table 8–18. Our estimate for oil is significantly lower than the generic estimate. In our no coal scenario, most coal plants are replaced by diesels. Because both fuels are imported, coal prices are relatively higher in Sri Lanka than is generally the case, so the difference between the two will be smaller. Our maximum hydro, and mini-hydro scenarios are at the low end of the range, although wind is again significantly lower.

Technology Intervention Compared with Price Reform

How do fuel and externality taxes compare to direct interventions in the electricity system? In figure 8–31 we now add the pricing policy cases examined earlier in this chapter to the tradeoff space. It is clear from

Table 8–18: Cost of CO_2 abatement using different technologies relative to a coal-based plant (in US$/tonne CO_2)

Technology	GEF range	Sri Lanka	Scenario
oil	45-89	14	no coal
large storage hydro	9-133	52	maximum hydro scenario
small storage hydro	45-223		
run of river hydro	44-222	47	mini-hydro
wind	6-223	48	wind

Source: London Economics(1992),Table 6.2

these results that pricing policy changes have a much greater impact than technology interventions. An examination of the tradeoff curves for other environmental indicators (health effects, acid rain, and so on) show similar results.

Externality Taxes

Economic theory requires that the efficient level of the tariff reflects not just the LRMC of the utility, but would also include the cost of environmental externalities. Assume for the moment that the principal externality of interest is the damage associated with the emission of greenhouse gases, which in the case of the power sector means carbon dioxide emissions resulting from fossil fuel combustion. Thus, in a fourth pricing policy scenario, the tariff is increased to reflect this externality value. The externality tax is assumed paid to the government.[86]

The consequences of this, and other, tax options are potentially complex, and the empirical results need to be placed in the context of theoretical expectations. Consider the diagram of figure 8–32, which depicts the solution space for feasible options in terms of total cost[87] and environmental impacts (for the sake of argument, GHG emissions). Assume that for some base case set of fuel prices, the least-cost solution lies at Z, with cost C_z and emissions E_z.

Now assume that an externality tax is imposed on the tariff, for instance in the form of a tax on carbon emissions at the rate T. Sup-

Table 8–19: The Impact of a carbon dioxide externality tax: year 2005

	base case	US$ 100/ton	US$ 200/ton
levelized tariff, Rs/kwh	3.21	3.36	3.49
PV(system cost)	`2959	2,850	2,813
year 2005 values			
demand, gwh	7,302	7,173	7,116
tariff, Rs/gwh	3.9	4.2	4.4
expansion plan impacts	600 Mw coal 120 Mw diesel	600 Mw coal 60 Mw diesel	600 Mw coal 60 Mw diesel
CO_2 emissions [1000t]	3,731	3,597	3,539
Carbon emissions [1000t]	1,019	982	966
reduction in carbon emissions [1000t]		37	52
Taxes			
externality tax [Rs billion]		2.2	4.2
BTT[Rs billion]	1.3	1.4	1.5
import duty[Rs billion]	3	2.6	2.3
total government revenue [Rs billion]	132.6	134.9	136.3

pose for the moment we simply elect to pay the tax, and that there is no price effect. Then the quantity of fuel consumed remains unchanged, because under this assumption consumption does not change in response to higher prices, and the solution moves at point X. Emissions remain at E_z, but costs increase to C_x. Note that the slope of the line Z-C_x is exactly equal to the rate of tax. The revenue raised is $T\,E_z = C_x - C_z$.

Now assume that there is a price effect. Then if the expansion plan remains unchanged, the solution shifts to point W. If we make the assumption that the marginal plant in the merit order is fossil fueled (which is generally the case, and certainly is true for Sri Lanka), then the solution at W is necessarily lower in cost and lower in emissions than at X, because only the quantity of fossil fuel consumed has changed, as the marginal plant is dispatched less in response to price induced lower demand.

Finally, if we also permit adjustments in the investment plan, the solution will shift to some solution V, which will be further to the lower left than point W. If we subtract the tax collected at this point ($E_Y\,T$) from the total cost, we obtain some point Y, which will lie below Z: this is now the system cost. The system cost with the tax (Y) will necessarily be less than the system cost in the absence of the tax (Z).

Table 8–20: The Impact of a Carbon Tax on Fuels

	base case	\$100/ton	\$200/ton
levelized tariff,Rs/kwh	3.21	3.46	3.57
PV(system cost)	2,959	3,470	3,740
year 2005 impacts			
demand, gwh	7,308	7,271	7,373
tariff, Rs/kwh	3.9	4	3.7
expansion plan impacts	600 Mw coal	300 Mw coal	0Mw coal
CO_2 emissions [1000t]	3,721	2,415	1,133
Carbon emissions [1000t]	1,016	659	309
reduction in Carbon emissions [1000t]	0	356	707
Taxes			
Import duty paid by CEB [Rs billion]	2.8	2.4	0.8
BTT paid by CEB [Rs billion]	1.3	1.3	1.3
fuel tax paid by CEB [Rs billion]	0	3.4	2.7
total government revenue, [Rs billion]	132.6	135.3	133.2

Figure 8–33 shows the simulation results for tax levels of US$100 per ton and US$200 per ton of carbon. The results exactly match expectations. Table 8–19 summarizes the major impacts for a particular year, 2005. The impacts on the expansion plan are rather modest. Even at US$200 per ton, there is little difference to the base case. This is consistent with expectations, for the sole impact of the tax is to depress demand, and hence the least-cost capacity expansion algorithm responds only to lowering of the demand projection that follows from higher prices.

Carbon Taxes

Finally there is the option of imposing a carbon tax directly on fossil fuels. The tax is based on carbon emissions from combustion, and is adjusted for the carbon content of the fuel in question. Given the earlier discussion of the order of magnitude of the tax that has been found necessary in other countries to achieve carbon emission reductions, we examine, for the moment without comment about the possibility of implementing such taxes, rates of tax of US$50, US$100, US$150, and US$200 per ton of carbon.

Figure 8–34 shows the results of the corresponding model simulations. The least-cost adjustments indicated here are for changes in generation mix only, and using only conventional technologies—and thus indicate what can be achieved by moving from coal to a mix of oil and hydro. In addition, as the cost of the tax gets reflected in the tariff, there is an additional adjustment due to price elasticity effects.

How do carbon taxes on fuel compare with externality taxes? As shown in figure 8–35, carbon taxes on fuel inputs typically have three times the impact of the corresponding externality tax. This result of course follows from the structure of the model, noted previously: the adjustment in the capacity expansion plan in response to the externality tax is simply the adjustment that follows from any lowering in the demand forecast, rather than any avoidance of carbon intensive fossil fuels.

Table 8–21: The Impact of Carbon Taxes (carbon reductions as percent of the baseline estimate)

	Country	US$ 100/tonC	US$ 200/tonC
US Congressional Budget Office	USA	10-20%[1]	
Nordhaus and Yohe	USA	27%	43%
Bye, Bye & Lorentsen	Norway	20%[2]	
Kram & Okken	Sweden		70%[3]
Meier & Munasinghe	Sri Lanka	24%	46%

estimates as reported in Pearce (1990).

(1) For $113 $/ton C, reduction relative to 1990 level by 2000

(2) $126/ton C, reduction by 2000.

(3) interpolated value for tax rates of $160 and $250/ton C.

In contrast, carbon taxes on fuels are seen directly by the expansion algorithm or a least-cost seeking utility—with the result that oil, hydro, and, where available, gas technologies replace coal. The US$100 per ton externality tax has little impact on the capacity expansion plan, as compared to the base case. The US$100 per ton fuel tax case, however, results in diesels replacing all coal units beyond 2004. Obviously, this particular result is also a function of the oil price forecast. In the case of the high oil price scenario, hydros replace some of the diesels, as they do when the level of the fuel tax is increased further.

The potential impact of fuel taxes is summarized in table 8–20 and figure 8–36. Fuel taxes potentially account for almost 7 percent of total government revenue,[88] and, as indicated in the figure, both fuel taxes and import duties are significantly more important than the business turnover tax (BTT). Clearly, a potential increase of government revenue of the order of 5 to 7 percent constitutes a transfer payment that may have significant broader macroeco-nomic effects.

The fate of such tax revenues would surely be fiercely contested. One option is to return it to the utility and its consumers. Certainly, in the early years, the most obvious such mechanism would be to exempt the utility from BTT. By the end of the decade, we might also then lower the import duty on equipment to provide rough revenue neutrality (that import duties to decline after 2007 is an end effect of the model).

Another option would be to put some or all of such fuel tax revenues into an earmarked trust fund to be used for reforestation and forestry sector programs: this is the environmentally desirable option. At lower rates of fuel tax the impact on the electric sector might be smaller, and the impact on GHG emission reductions is also lower, perhaps at values of US$20 per ton, more commensurate with the cost of carbon sequestration through forestry programs. Clearly, at rates in excess of US$50 per ton of carbon, revenues would substantially exceed equivalent forestry costs.

Comparison with Other Studies

Both Nordhaus (1991) and Pearce (1991) have surveyed the many studies that have examined the impact of carbon taxes. None appears to have been made for any developing countries. In Sri Lanka, the impact of carbon taxes on electricity generation will be a shift from coal to diesels, and then to large hydros. The concomitant electricity price increases also significantly depress demand—for example, the base case levelized tariff of 3.08 rupees per kilowatt hour rises to 3.44 rupees per kilowatt hour with a tax of US$100 per ton of carbon. What is fascinating is that our estimates of the impact of fuel taxes are so remarkably close to those for developed countries, as shown in table 8–21.

Transportation Sector Options

In figure 8–37 we show the tradeoff curve for the transportation sector options examined, as discussed earlier in this chapter, and summarized in table 8–6. In place of electric sector system costs, we now use total energy sector costs, which also includes the total petroleum import bill, to reflect the impact of improvements in fuel economy. In place of electric sector emissions, we now include all energy sector related GHG emissions. To provide some reference point to the previously examined electric sector interventions, we also include on this figure the solutions for wind, no coal and CFL.

The results indicate the importance of maintaining an efficient urban mass transit system to GHG emissions. If the share of passenger miles to autos increases, both sector cost and GHG emissions will increase. On the other hand, the benefit of vehicle I/M programs is clearly evident, bringing a 2.5 percent reduction in carbon dioxide emissions and a decrease in system cost because the fuel cost savings exceed the costs of the inspection program.

Although the reduction in the fraction of two-stroke motorcycles has limited effects on GHG emissions, however, it does, as anticipated, bring dramatic improvements to particulate emissions and concomitant health impacts. This is illustrated in figure 8–38. Vehicle I/M programs also bring significant particulate emission reductions.

Thus, a vehicle I/M program is an almost textbook case of a win-win policy. It brings significant improvements to local, urban air quality. It reduces both fuel consumption and GHG emissions—a global environmental impact.

The Cost Curve for GHG Emissions

With the above results in hand, we are now in a position to develop an optimal portfolio by combining the various options in such a way as to provide a progressive decrease in GHG emissions (see figure 8–39). We begin with pricing reforms, moving from business as usual (3 percent return) to the base case (8 percent return) and to AIC pricing.

Next we introduce the win-win measures encountered in quadrant III of Figure 8–26: the DSM measures (EEF and CFL), and lower T&D losses. Obviously, the result of the combination of these three measures is not necessarily equal to the sum of the individual measures indicated by the dashed arrows. The least-cost strategy is then reached by the addition of the vehicle I/M program.

Achieving further reductions in greenhouses gases now entails costs, and thus the cost curve moves upwards again. First we introduce clean coal plants, then wind plants, then exclude coal, and in a final, but high cost step, we force in the entire portfolio of hydro plants. It is on this part of the curve that the incremental cost is equivalent to the GEF definition, and therefore potentially eligible for GEF funding.

This can be redrawn with different axes, and, for illustrative purposes, Figure 8–40 shows the reduction in the tons of carbon dioxide emitted per year (in 2011) that can be achieved by progressive inclusion of measures into the optimal portfolio. Thus the results are displayed in terms of cost changes with respect to the least-cost case, and GHG emission savings with respect to the business as usual case. See figure 8–41 for a comparison of Sri Lanka's GHG reduction with that of other countries.

Conclusions

Pricing policy has a more general impact than physical approaches to demand side management. DSM programs are difficult to implement, and limited in scope. Moreover, even though the results of this study appear to suggest that compact fluorescent lighting in particular is highly cost effective, it must be stressed that there is almost no data on end use electricity demand in Sri Lanka, and that therefore the predicted changes to the load curve are subject to considerable uncertainty.

While some measures to reduce GHG emissions imply a significant increase in other local environmental impacts, these measures also tend to be very expensive, and therefore unlikely to be implemented. The maximum hydro-no coal scenario, which brings very large GHG emission reductions, would have a high impact on biodiversity because some of the larger hydro projects, such as the high dam variant of the Kukule project, would inundate forests of high biodiversity value. This option also increases the system costs significantly. Among those measures that are more modest in cost—or even those, like certain DSM measures that will reduce costs—there is a coincidence of global and local impact reduction. Thus PFBC, LRMC pricing, and wind all reduce GHG emissions and reduce local air quality related health impacts.

The use of FGD systems for sulfur dioxide control emerges as a particularly poor option. Indeed, the results emphasize the importance of making decisions about FGD systems at the planning rather than at the project level. If indeed FGD systems are to be required at coal plants, it may be that coal plants ought not to be built at all. At least in the case of Sri Lanka, a policy that would

Table 8–22: Impact of Welfare Losses

	base case	no coal	wind	CFL	$100/t e(tax)
PV(demand)	34,057	33,337	33,688	33,415	33,238
levelized tariff,Rs/kwh	3.21	3.26	3.35	3.17	3.36
PV(electric system costs)	2,959	3,021	3,072	2,749	2,850
Cost savings					
cost savings		-63	-114	247	108
tax revenue					355
increase in consumer surplus		-36	-109	131	-117
increase in producer surplus					-243
total savings (cost)		-99	-222	378	104
CO_2 emissions (1000tons)					
undiscounted CO_2 emissions (to 2011)	56,473	42,436	50,250	54,845	53,549
reductions in CO_2 emissions		-14,038	-6,224	-1,628	-2,924
reduction in C emissions		-3,835	-1,700	-445	-799
cost, $ per ton C avoided					
supply cost impact only		16	67	-472	-136
with all impacts included		26	131	-538	-130

(1)negative amount signifies a cost saving as well as a decrease in CO_2 emissions.

require FGD systems results in the least-cost system moving to diesels and hydro plants. In any event, new clean coal technologies such as PFBC reduce not only sulfur dioxide emissions, but particulates, NOx, and carbon dioxide emissions (per kilowatt hour generated) as well. And, finally, when we examine impacts such as the value of the health index, rather than just emissions, such as sulfur dioxide emissions, it becomes obvious that fitting FGD systems to remotely located coal plants with high stacks brings little reduction in impacts in comparison to measures taken at older urban fossil plants with typically short stacks that burn high sulfur residual oil in close proximity to population centers.

Annex 4. Consumer Impacts and Welfare Losses

The tradeoff curves thus far presented do not capture a number of other important impacts. As with any tax, certain welfare losses arise that need to be considered. Figure 8–42(a) illustrates this issue. The initial price and quantity corresponding to the base case are (P_o,Q_o). The impact of the tax is, in effect, to shift the supply curve as seen by consumers upwards, with the new price and quantity at (P_t,Q_t). Consumer surplus decreases by the area (2)+(3)+(4), while producers' surplus falls by the areas (6)+(8)+(5). The tax revenue is $Q_t \times T$, which corresponds to the area (2)+(3)+(6)+(8), and hence we have the well-known result that the net welfare loss associated with the tax is the triangle (4)+(5), as indicated[89].

Figure 8–42(b) shows the corresponding situation for wind energy. By forcing wind plants into the expansion path the actual supply curve shifts upward, and the supplier is at F, rather than at G. While the loss of consumer surplus is again the sum of (2)+(3)+(4), the producer surplus shifts from [6+8+5+7] to [2+6], hence the net welfare loss is the indicated polygon equal to the areas [7+8+3+4+5].

How important are these effects in practice? Certainly in the United States a vigorous debate has arisen during the last few years in connection with DSM programs as to whether changes in customer value should be included together with avoided supply costs and environmental benefits in assessing the merits of alternative DSM program options.

Table 8–22 compares the base case, wind energy, no coal, CFL and a US$100 per ton externality tax. When consumer impacts are taken into account, the cost for both wind and no coal are seen to roughly double. By the same token, the impact of CFL increases by about 25 percent when the increase in consumer surplus that follows from the rate decrease (from a levelized value of 3.21 rupees per kilowatt hour to 3.17 rupees per kilowatt hour) is taken into account.

To be sure, we are mindful of the hazards of drawing general policy conclusions from partial equilibrium analyses. Nevertheless, it is hard to avoid the conclusion that the cost of reducing GHG emission falls when changes in consumer value are taken into account and that the results do indeed differ significantly from the conventional assessment that considers only changes in supply cost.

Annex 5. Impact of GHG Emission Reduction Measures on System Reliability

ENVIROPLAN does not have the ability to optimize system configuration for given loss of load probability. Rather, it optimizes system configuration based upon some particular value of the price of unserved energy, which, in the base case, we take as 20 cents per kilowatt hour for consistency with the WASP generation planning studies by the CEB. Total system cost includes a term for the value of unserved energy, PV(uns) which is given by

$$PV(uns) = \sigma \sum \frac{\sum_{h=1}^{h=3} D_{jh}-E_j}{(1+r)^j}$$

where D_{hj} is the energy dispatched in year j in hydro condition h, E_j is the generation requirement in year j, [sigma] is the cost of unserved energy, in U.S. dollar per kilowatt hour, and r is the discount rate. In this analysis we use three hydro conditions, as in the CEB WASP model planning studies. (This is a simple approach to optimizing reliability. For a more sophisticated approach, see Munasinghe 1990.)

ENVIROPLAN adds system capacity to meet an exogenously specified planning reserve margin (PRM) — similar to the procedure used in a number of well-known planning models developed by EPRI such as the classic Over/Under model and the more recent MIDAS model.[90] If desired, the planning reserve margin constraint can be included as a model variable, but at the cost of considerably increased computation times. This proves generally unnecessary, because there is a good correlation between the value of unserved energy assumed and the value of the PRM that minimizes system cost.

This is illustrated in figure 8–43, which shows the relationship between system cost and unserved energy for values of unserved energy of 20 cents per kilowatt hour, and 50 cents per kilowatt hour, the latter again being the value used in CEB planning studies for their high unserved energy cost case.

As we might expect, the higher the value of unserved energy, the more the curve shifts to the right: at 20 cents per kilowatt hour, the optimum value of PRM is 35 percent; at 50 cents per kilowatt hour, the optimum value is 55 percent.

What is the impact of some of the GHG-emission options upon system reliability? In figure 8–44 we show a plot of unserved energy against total system cost for the base case, and for the wind energy scenario, using a value of 20 cents per kilowatt hour as the cost of unserved energy. The minimum is seen to lie in the vicinity of a PRM value of 35 percent in both cases, although the value of unserved energy is smaller for the wind scenario. Thus, under least-cost conditions, the reliability of the system increases when wind power is forced in.[91]

It should, however, be noted that in the case of measures that dramatically change the shape of the load duration curve, the PRM value needs to be changed. For example, as shown in figure 8–45, for the compact fluorescent lighting (CFL) option, the minimum system cost occurs for a PRM of about 70 percent, almost double the value of 35 percent that we use in the other cases.[92]

Another way of looking at this issue is to exclude the value of unserved energy from the system cost attribute—perhaps desirable anyway in light of the uncertainty that surrounds the estimation of a specific value for cents per kilowatt hour unserved—and then include reliability as an additional non-monetary attribute in the multi-criteria analysis (MCA).

The results are shown in figure 8–46. We see that most measures that significantly affect GHG emissions, including the no coal option, do not result in a significantly different level of system reliability, shown here on the *x*-axis as the percentage of total demand unsatisfied. Wind, and a properly calibrated CFL case (that is, with a 70 percent PRM), show improved reliability, whereas the maximum hydro cases show significantly decreased reliability. If reliability were to be held constant for these maximum hydro scenarios, then the system cost would increase even further.

Annex 6. Discounting of Greenhouse Gas Emissions

The question of the choice of discount rate has been fiercely debated by both economists and environmentalists, and a review of this literature goes well beyond the scope of this study. The consensus view is that the opportunity cost of capital, with discount rates in the range of 6 to 12 percent, is appropriate for environmental cost benefit analyses. This annex does not join the debate itself, but addresses the much simpler empirical question: does the choice of the discount rate for the physical flows make a difference to the results?

In the tradeoff curve analysis presented in this report we have used a 10 percent discount rate for economic attributes, corresponding to the rate currently used in the system planning studies of the Ceylon Electricity Board (CEB).

Figure 8–47 shows the impact of the various alternatives considered for definition of the physical quantities. Case A applies a 10 percent discount rate to the GHG emissions (equal to the discount rate used for system costs). Case B uses undiscounted GHG emissions: in other words, displays the total GHG emissions between 1992 and 2011. Case C simply displays the results in terms of carbon dioxide emissions in a given year (2011).

The results are seen to be robust with respect to the criterion used. While the shape of the curve shows some small differences, in all three cases, the options and technologies that lie on the tradeoff curve are the same.

Accounting For Risk And Uncertainty

Over the past few years increasing concern has been expressed about the robustness of least-cost expansion plans with respect to the many uncertainties that characterize energy planning (see, for example, Crousillat 1989 and Crousillat and Merrill 1992, or Meier 1990). Least-cost plans are typically optimal only for a rather narrow band around the particular set of assumptions used. In some cases, even small changes in input assumptions may make a least-cost plan distinctly non-optimal.

This concern is well illustrated by Sri Lanka's generation capacity expansion plans, which are developed with the WASP model. In figure 8–48 we show the projected capacity additions in the period 1992-05 in four successive annual studies, as published in the official CEB plan. We also show a fifth projection, in which the WASP model was rerun for 1992 without any exogenous constraints.

These are indeed abrupt changes in the generation mix, which require some explanation. The first issue concerns the optimality question itself. It appears that the so-called least-cost plan, as presented in the CEB report, is not least-cost at all, even for the scenario assumptions chosen. In fact, in 1989, 1990, and 1992 the hydro capacity shown was forced into the solution, on the grounds that these projects were already in the pipeline. Indeed, the system present value for the unconstrained run is US$1,724 million for the unconstrained case, and US$1,776 million for the CEB base case. This US$50 million may not appear very large (for example, the CEB estimate for the high fuel cost case is US$1,941 million), but the environmental impacts of the two plans are very different.

Then there is the issue of the demand forecasts. The civil disturbances in the late 1980s had a dramatic effect on electricity consumption, as noted earlier in this chapter. The sudden changes in growth rate of demand, which was negative 1989, and the general air of pessimism about the future, colored the projections made by CEB, long term trends notwithstanding.

The exact opposite occurred two years later. In 1992, after a year in which demand growth increased by 10 percent, the growth rate that represented the basis for the forecast was increased. As a result, the peak load forecast for 2005 went from 1,766 megawatts in 1991 to 2210 megawatts in 1992 (table 8–23: also see figure 8–49).

Table 8–23: Year 2005 Load Forecast

year of study 2005	*peak demand, Mw*
1989	1,848
1990	1,673
1991	1,766
1992	2,210

This tendency for current events to color forecasts is hardly limited to electricity demand projections. World oil price forecasts, for example, have been notoriously subject to the psychology of the day, rather than to any realistic appraisal of long term trends.

Figure 8–50 illustrates the significant changes in input assumptions from year to year in the case of hydro project assumptions, which compares model input values in 1991 and 1992. Two hydro projects were dramatically cut in size (Kukule from 144 megawatts to 70 megawatts, and the Upper Kotmale from 243 megawatts to 123 megawatts)[93]; and all of the others showed changes in energy and capital costs that resulted in major increases or decreases in specific cost. In the case of Kukule, for example, the change was a consequence of the results of the ongoing feasibility study, which showed the smaller run-of-river project to have lower unit costs and very small relocation impacts.

Such changes in input data are unavoidable, although we do not advocate that planning studies ought not to use the most current information available. This should not be taken as a criticism of CEB, whose recent generation planning studies have not only improved dramatically, but have also included a much greater range of sensitivity analyses than elsewhere. Our intention is to make the points that (1) the uncertainty that surrounds hydro assumptions are much greater than those that surround thermal plants; (2) demand projections are far too sensitive to recent events; and (3) much greater attention needs to be given to the robustness of proposed plans. At a very minimum there is a need to examine the impact of forecasts for oil prices, demand growth, and so on that run counter to the current judgment of the experts on these matters.[94]

How robust are the conclusions with respect to the kind of uncertainties discussed above? Perhaps more importantly, the experience of the past decade suggests that institutional and regulatory uncertainties may play as critical a role as the more frequently cited concerns over the future world oil price, or overly optimistic estimates of the cost of new technology. How are such institutional uncertainties to be considered? These questions need to be addressed in our study as well.

Foremost among institutional uncertainties is the extent to which private power projects can be integrated into state owned systems in an economically efficient manner.[95] We need look only to India to recognize this point: all of the technical uncertainties cited above pale to insignificance compared with the uncertainty surrounding, for instance, the proposed ENRON project in Maharashtra, which would in a single project dramatically change the entire generation, tariff, and cost structure of the State Electricity Board.[96]

Options and Scenarios

The first step is to be clear about the distinction between options and scenarios. Options are those variables that are within the control of national decisionmakers: imposing a new pricing policy, choosing a siting policy, excluding or adopting a particular new technology. Combinations of options are termed strategies. Options represent the branches at decision nodes of a decision tree.

On the other hand, there are the variables that are not within the control of national decisionmakers, such as the world oil price or consumer behavior, which are—termed scenarios. These represent the chance nodes of a decision tree. For some variables the distinction may be practical rather than conceptual. For example, how much influence policy makers have on economic growth is usually the subject of some controversy. For practical reasons in a power sector planning study, economic growth rates that drive demands are best taken as exogenous. Population growth rates is another example of where the correlation between policy action and outcome is sufficiently uncertain to warrant treatment for an energy or electric sector planning study as an exogenous uncertainty rather than policy option. A combination of scenarios is termed a future.[97]

The elements of uncertainty

The list of potential uncertainties faced by the energy and electricity planner is a very long one indeed. In our study we considered only that set of issues deemed most applicable to the situation in Sri Lanka.

Construction time uncertainty: The burden of interest during construction for capital intensive projects of long gestation time makes investment plans especially sensitive to assumptions about construction delays, regardless of whether the delays are due to utility or contractor mismanagement, environmental opposition and litigation, or *force majeure* occurrences. In this study we define three construction time scenarios: (1) a reference case, in which we use the construction schedule assumptions of the Ceylon Electricity Board (six years for a coal unit, two years for a combustion turbine, four to five years for larger hydro plants); (2) a delay case, in which large coal and hydro plants are assumed to take an additional year to complete (identified on the tradeoff curves as +ct), with a prorated adjustment in the timing of construction outlays;[98] and (3) a severe delay case, in which the delay is assumed to be two years, attributable to litigation that occurs four years after construction commencement, during which time construction activity is suspended (+++ct). Clearly this results in significant increases in interest during construction (IDC).

The rationale is that large hydro and coal plants are the ones most likely to incur delays. In Sri Lanka, indeed, geological uncertainties have played a significant role in delaying startup of the last two major hydro projects;[99] smaller run-of-river plants are assumed less likely to incur delays, not just because engineering geological uncertainties tend to be less, but primarily because they largely avoid the problems associated with resettlement of inundated villages.[100]

Capital cost uncertainty: while the construction delay scenarios outlined above have the equivalent effect of increases in capital costs, it is reasonable to assume that the costs for some of the new technologies considered in this study may in fact decrease. Whilst it is true that the costs of many new technologies are typically underestimated in the early stages of R&D, it is not unreasonable to suppose that the costs of some renewable energy technologies may decrease over the next decade, always assuming that our reference case uses realistic costs for current conditions. Wind, photovoltAIC, and even some clean coal technologies are likely to benefit from continued R&D over the next decade. We therefore define a low capital cost scenario, in which the real capital cost is assumed to decline 0.5 percent per year for wind and clean coal (in our case PFBC) technologies (-CC).

World oil prices. The reference case in our study uses, as does the 1992 generation planning study of the CEB, the 1992 World Bank world crude oil price projection, which calls for a gradual increase in 1992 U.S. dollars from US$16 per bbl in 1992 to US$21.4 per bbl (fob Singapore) by 2000, and constant thereafter. In our high case (+wop), we assume the price continues to rise after 2000 reaching US$29.4 per bbl by 2010. In our low case (-wop), we assume that after an initial increase, the price falls, to US$15.30 per bbl by 2010.

These are the conventional ways of treating world oil price uncertainties. Yet, as shown by our analysis, such gradual changes tend to have a rather small impact. Moreover, as we review the experience of the last two decades, what causes real problems for planners are large swings that typically persist for many years, and then reverse rapidly. Moreover, what matters, at least for utility planners, is not so much crude oil prices, but the price of heavy fuel oil—in Sri Lanka, for example, the two primary competitors for thermal generation are coal and low speed diesels—and fuel oil price swings are even greater than crude oil price swings.

Consequently we also define a world oil price scenario in which the real price of crude oil and fuel oil rises to US$38 per bbl in 1999, and US$40 per bbl in 2000; then parallels the trajectory of the 1980s with a slow drift downwards, a sudden collapse in 1985 (2005), followed by a gradual increase back to US$20 per bbl by 2010. Clearly history is not likely to repeat itself exactly, but such an oil shock scenario is probably a lot more likely than gradual changes. Figure 8–51 summarizes the various oil price scenarios.

Consumer behavior. How consumers react to changes in the electricity price is captured econometrically by the price elasticity of demand. Whatever may be the statistical significance of the estimated values based on historical data, there remains substantial uncertainty as to what future price elasticity may be. In the reference case we use the historical value of -0.2; in the low elasticity case we use -0.07 (-e), and in the high case -0.3 (+e).

There are other relevant uncertainties. One concerns demand side management technologies, in our case compact fluorescent lighting (CFL) and energy efficient refrigerators. In the case of CFLs we can make estimates of the energy savings from the power rating of the bulbs assumed. There is evidence of a strong rebound effect, though, where actual savings may be much less than estimated because consumers respond to lower rates by using more electricity (if CFLs lowers the lighting bill by a factor of three to four, there is less incentive to switch unused lights off!). In the high elasticity case, therefore, we assume that CFLs produce only 60 percent of the reference case energy and power savings. The rationale here is that if consumer respond to higher prices by significant decreases in consumption, we might in the interests of reducing the number of combinations of scenarios assume that those same consumers would respond to decreases in their electric bills due to CFLs with an increase in consumption.

Economic growth. As noted in the introductory remarks, for purely practical reasons assumptions about the future rate of GDP growth are best handled as an exogenous uncertainty. To include GDP growth as an endogenous variable in the modeling framework would vastly increase the complexity of the model, and inevitably raise a range of issues about the adequacy and validity of any conclusions given a whole host of additional uncertainties about macroeconomic relationships in general, and the impact of changes in electricity and energy prices or balance of payments, upon growth rates. In the reference case as used by CEB we assume 5 percent annual GDP

Table 8–24: Futures Definition

Uncertainty	low stress	basecase	high stress
World oil price	basecase	basecase (25$/bbl in 2000)	oil shock scenario
consumer behavior	high price elasticity of demand	basecase (as estimated from historical data)	low price elasticity; for CFL, high rebound effect(1)
environmental opposition	basecase	basecase	longer construction periods for hydro and coal (+ 2-years)
capital costs for new technologies (wind, DSM technology, PFBC)	optimistic 2% per year improvement over basecase	basecase	basecase
economic growth (real GDP growth)(2)	low (3.5% per year)	basecase (5% per year)	high (6% per year)

growth; in the low case (-gdp) this is reduced to 3.5 percent, and in the high case (+gdp) increased to 6 percent.

Uncertainties in income elasticities could be treated explicitly as well; but from the standpoint of the demand projection, whether the change is due to an increase in GDP growth rate, or a higher income elasticity amounts to the same thing.

Uncertainties in government policy. Current rates of duty on imported capital goods is 30 percent. This has to be paid by the CEB on imported electricity generation equipment, and amounts to a significant burden on rates, accounting for as much as 18 percent of revenue requirements in some years (see figure 8–52). Certainly if we look at the experience of other countries, rates of import duty on such equipment are one of the major concessions made to private power developers. Even though we make no explicit assumptions about private power in Sri Lanka, private power development is now being encouraged by the government, and it is not at all unlikely that the next diesel unit, and several mini-hydros, will be developed and financed by foreign consortia. With India having just reduced its rate of import duty on power generation equipment (from 30 percent to 20 percent) as an inducement for overseas private foreign investment, a similar step may also be a possibility for Sri Lanka. We therefore define a low tax case (*-t*), in which the rate of duty is lowered from 30 percent to 5 percent.

Futures

For obvious reasons some approach has to be found to narrow the number of scenarios considered in a planning study or policy analysis: In our case, the number of possible combinations of all individual scenarios results in 432 possible futures.[101] One approach for reducing this to some practical number is to define a small number of futures that capture the range of combinations of outcomes. In this study we define futures on the basis of rate stress, on grounds that the degree of pressure on rate increases is the central concern of utility management. Perhaps in other situations the main concern might be capital mobilization. Whatever the criterion used, in general one selects some set of paths through the chance nodes of the decision tree, such that a representative range of outcomes is achieved. These may or may not be easy to select on an *a priori* basis, and some preliminary model simulations may be necessary. In Figure 8–53 we illustrate the definition of low, basecase and high stress futures through three levels of the decision tree. In Table 8–24 we show the full definition of futures considered in the Sri Lanka case study.

In Figure 8–54 we show the tradeoff between system cost and GHG emissions for the basecase pricing policy under the three futures considered. Obviously, since the futures differ significantly in economic growth and hence demand, the high stress case involves considerably higher system costs, and emissions, than in the low stress case. In all three cases, however, the advantage of AIC pricing and CFL is apparent.

More interesting is the appearance of wind in the tradeoff curve for the low stress future. With load growth low, and remembering that we have forced in 300 megawatts of wind capacity in the late 1990s, no additional fossil capacity is required until 2004, thereby substantially reducing emissions. The costs of wind remain high, but the costs of the maximum hydro scenarios are even higher, and hence the appearance of wind on the tradeoff curve.

Figure 8–55 shows the health effect tradeoff curves. Note that the spread in the high stress future is very much greater than in the low stress case: the difference in health impact between no coal, and noCoal+lowSoil is a factor of three in the high stress case, but only a factor of two in the low stress case. In other words, the absence of a compensatory siting or fuel quality policy if coal plants are eliminated as a GHG emission reduction measure carries high risks.

In Figure 8–56 we compare AIC and basecase pricing in the high stress future. The tradeoff curves do not differ greatly for either GHG emissions or health impacts, although the location of the curve in the tradeoff space is more favorably placed for AIC pricing (that is, nearer the origin). Note also the appearance of T&D+ on these curves, which was not the case in the low and reference futures. This is a simple consequence of the greater cost of losses when oil prices are high and demand growth strong.[102]

From all of these observations we draw the following conclusions:

- The earlier conclusions about the desirability of economically efficient pricing appear robust across all three futures.
- There are some differences in technology options across the three futures examined. Further reductions in T&D losses look particularly good in the high stress future.
- The elimination of coal plants as a GHG control measure in favor of a mix of diesel and hydros carries high risk. First, the obvious point of the impact of oil price shocks: coal price fluctuations have historically been much smaller, and not as volatile, as oil prices. More importantly from an environmental standpoint, unless accompanied by a stringent siting policy for diesels in combination with sulfur controls on residual oil, the local health impacts may be significant.

Conclusions

Setting electricity prices to reflect the LRMC has a significant, and unambiguously beneficial impact on the environment, both in-country and globally. The expected benefits predicted on theoretical and intuitive grounds are confirmed by the specific case examined. For example, the difference between an AIC-based tariff and one based merely on achievement of a financial covenant to assure a 10 percent rate of return is a 6 percent reduction of greenhouse gas emissions in 2010, and a 10 percent reduction in the health effects related to the exposure of human populations to the incremental ambient concentration of air pollutants.

It is true that the environmental benefits that follow from pricing reform are dependent upon assumptions about the price elasticity of demand. Even under the unlikely assumption of zero price elasticity, however, we can be sure that the environmental impact of pricing reform is not negative.

The imposition of carbon taxes on fuels has a more direct impact on greenhouse gas emissions, and other measures related to the use of fossil fuels, than adding the equivalent externality cost to the electricity tariff. Carbon taxes on fuels force direct changes in the investment plan to reflect the new relative fossil fuel prices, whereas externality taxes, while lowering electricity demands through price effects, do not necessarily reduce GHG emissions under least-cost system planning criteria.

Pricing policy has a more general impact than physical approaches to demand side management. DSM programs are difficult to implement, and limited in scope. Moreover, even though the results of this study appear to suggest that compact fluorescent lighting in particular is highly cost effective, it must be stressed that there is almost no data on end use electricity demand in Sri Lanka, and that therefore the predicted changes to the load curve are considerably uncertain.

Nevertheless, the results suggest that it is hard to justify more expensive measures for GHG emission control, such as wind energy, or the substitution of diesels for coal plants, if the more cost effective measures such as DSM, T&D loss reduction, and maximum implementation of mini-hydros, have not been implemented first.

A number of transportation sector measures, advocated on grounds of ameliorating local air quality impacts, or general improvements in the fuel efficiency of the sector, prove to have significant GHG emission reduction benefits as well. The introduction of vehicle inspection and maintenance programs would bring significant reductions in both particulate and GHG emissions. Most of the other road transport sector measures advocated by the Clean Air 2000 program for air quality improvement in the Colombo metropolitan area have a more limited impact on GHG emissions.

While some measures to reduce GHG emissions imply a significant increase in other local environmental impacts, these measures also tend to be very expensive, and therefore unlikely to be implemented. The maximum hydro–no coal scenario, which brings very large GHG emission reductions, would have a high impact on biodiversity because some of the larger hydro projects, such as the high dam variant of the Kukule project, would inundate forests of high biodiversity value. This option also significantly increases the system costs. Among those measures that are more modest in cost —or even those, like certain DSM measures that will reduce costs— there is a coincidence of global and local impact reduction. Thus PFBC, LRMC pricing, and wind all reduce GHG emissions and reduce local air quality related health impacts.

The use of FGD systems for sulfur dioxide control emerges as a particularly poor option. Indeed, the results emphasize the importance of making decisions about FGD systems at the planning rather than at the project level. If indeed FGD systems are to be required at coal plants, it may be that coal plants ought not to be built at all. At least in the case of Sri Lanka, a policy that would require FGD systems results in the least-cost system moving to diesels and hydro plants. In any event, new clean coal technologies such as PFBC reduce not only sulfur dioxide emissions, but particulates, NOx, and carbon dioxide emissions per kilowatt hour generated as well. Finally, when we examine impacts, such as the value of the health index, rather than emissions such as sulfur dioxide emissions, it becomes obvious that fitting FGD systems to remote coal plants with high stacks brings little reduction in impacts in comparison to measures taken at older urban fossil fuel plants with typically short stacks that burn high sulfur residual oil in close proximity to population centers.

GHG emissions reduction options may have a significant impact on system reliability. Wind energy will generally increase system reliability. Thus, in addition to the environmental benefit, there is a reliability benefit to be traded off against the additional cost. In the case of Sri Lanka, the maximum hydro scenarios will decrease reliability if the criterion is merely to find the least-cost system subject to forcing in all the large remaining hydro schemes. If for these scenarios we hold reliability constant, then the system cost increases even more.

Many of the results of this study are consistent with recent literature on the experience in the United States with respect to proper evaluation criteria for non-supply measures. In particular we find that when changes in consumer value are taken into account, many GHG emissions reduction strategies, such as wind energy plants, are much more expensive than when evaluated solely upon the basis of supply cost changes.

In summary, the emphasis given to efficient pricing in both project loans and adjustment lending is justified not only on grounds of economic efficiency, but also on grounds of minimizing the environmental damages of economic development. This report clearly and explicitly demonstrates that efficient pricing makes a significant contribution to environmentally sustainable development.

Abbreviations

AIC	Average incremental cost
BOO	Build-own-operate
CEA	Central Environment Authority (of Sri Lanka)
CEB	Ceylon Electricity Board
CFL	Compact fluorescent lighting
CMA	Colombo Metropolitan Area
DSM	Demand-side management
ESCAP	Economic and Social Commission for Asia and the Pacific
EEF	Energy efficient refrigerators
FGD	Flue gas desulfurization
HT	High tension
IDC	Interest during construction
GEF	Global Environment Facility
GHG	Greenhouse gases
GTZ	Gesellschaft fuer Technische Zusammenarbeit (German Technical Assistance Agency).
IEA	International Energy Agency
JICA	Japan International Cooperation Agency
LECO	Lanka Electricity Company
LRMC	Long-run marginal cost
MCA	Multi-criteria analysis
MEIP	Metropolitan Environmental Improvement Programme (of Colombo)
NAREPP	Natural Resources And Environmental Policy Project (sponsored by USAID)
OTA	Office Of Technology Assessment (of the U.S. Congress)
PC	Pulverized coal
PFBC	Pressurized fluidized bed com bustion
T&D	Transmission and distribution
USAID	United States Agency For Interna tional Development

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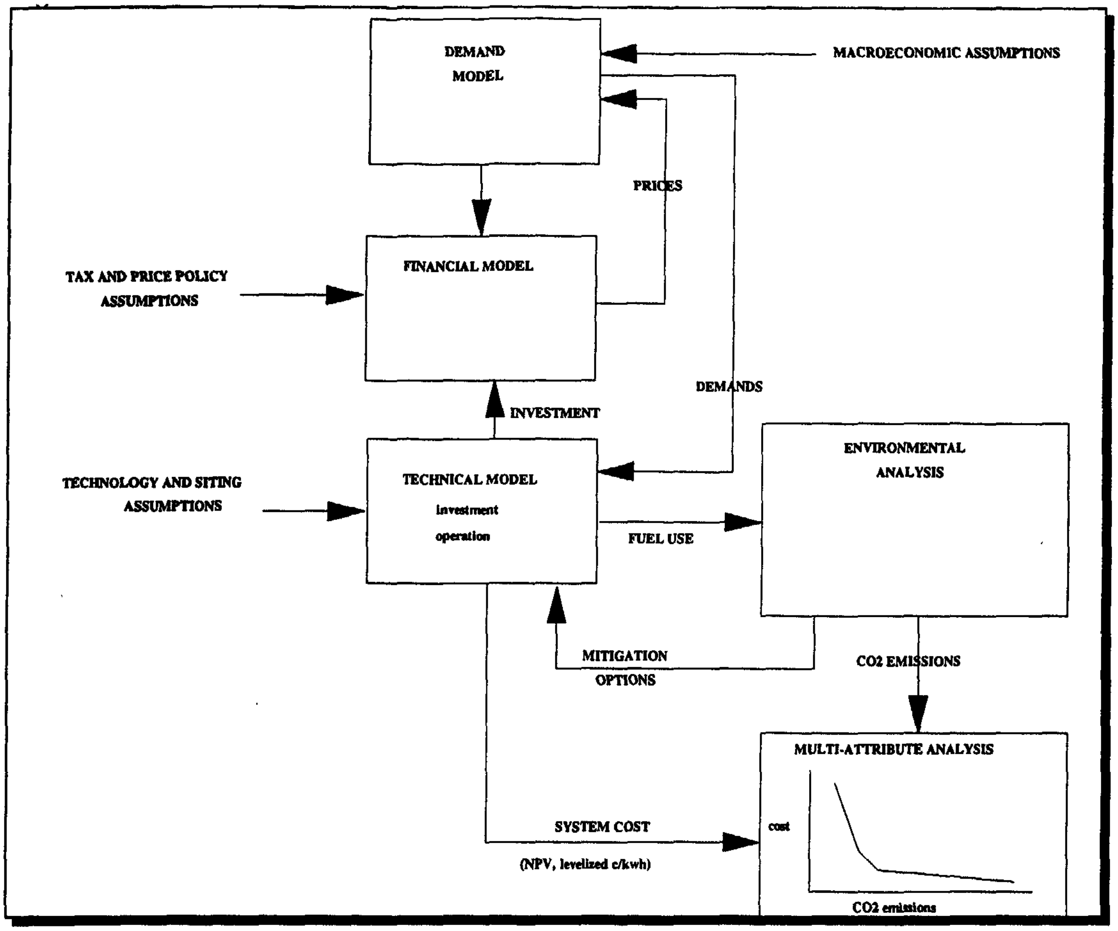

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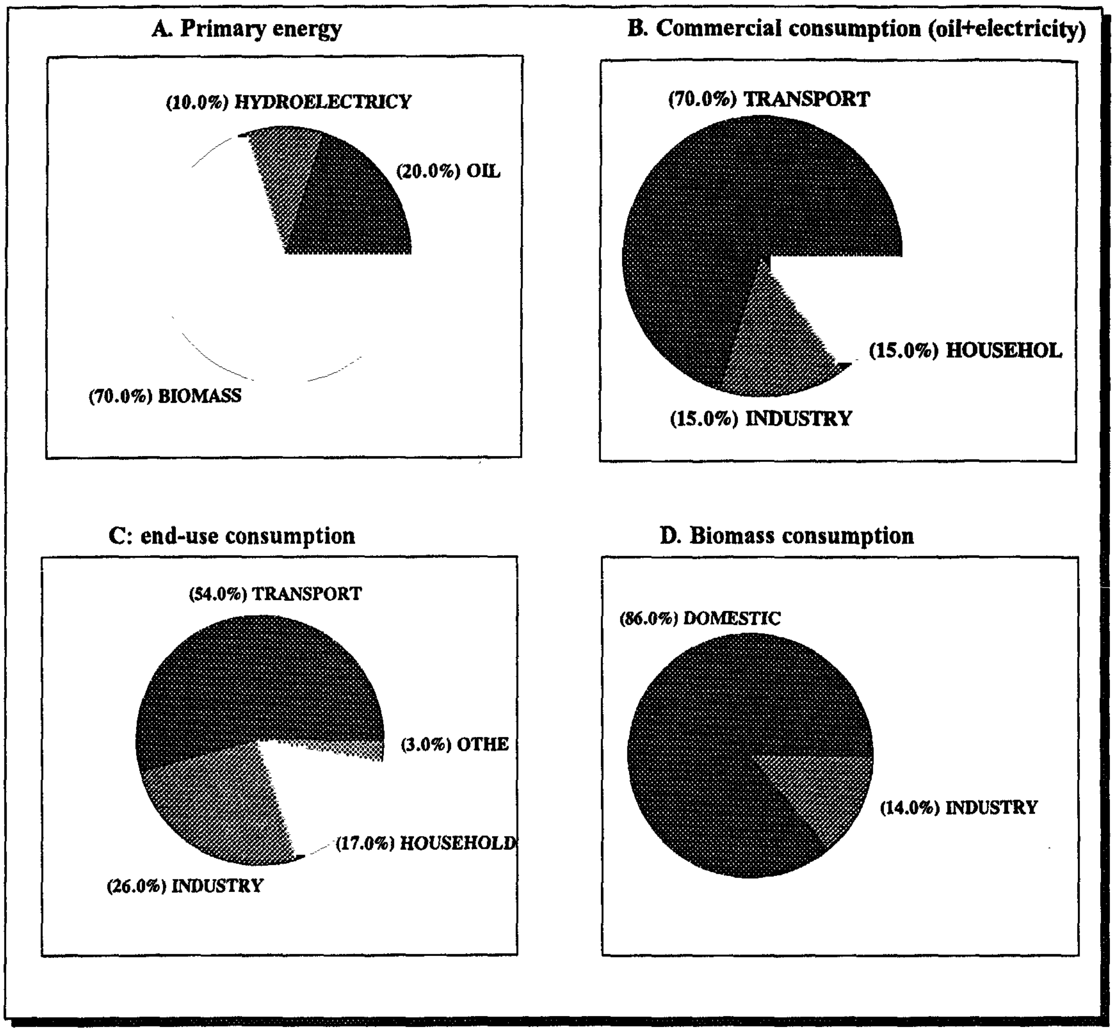

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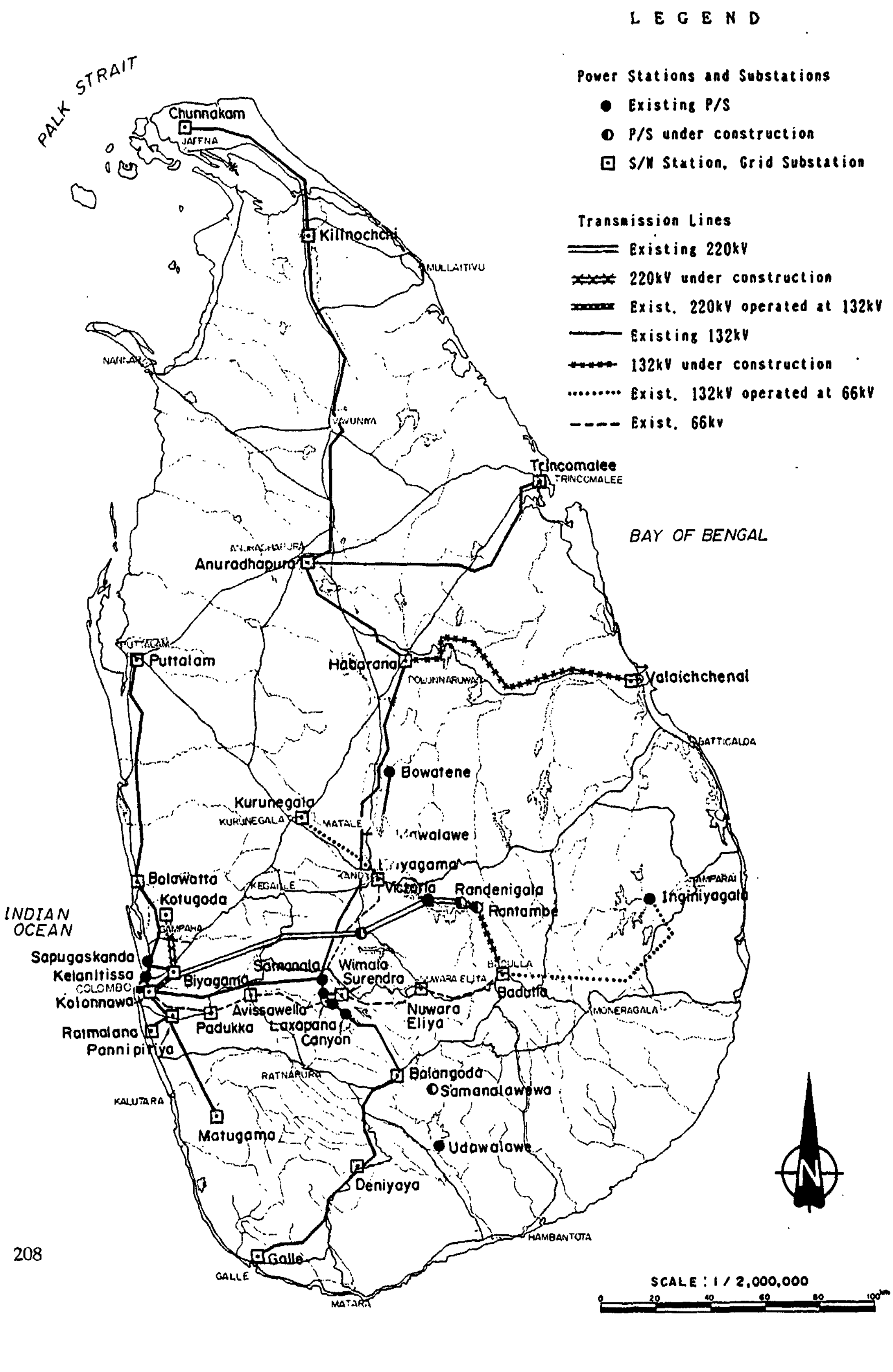

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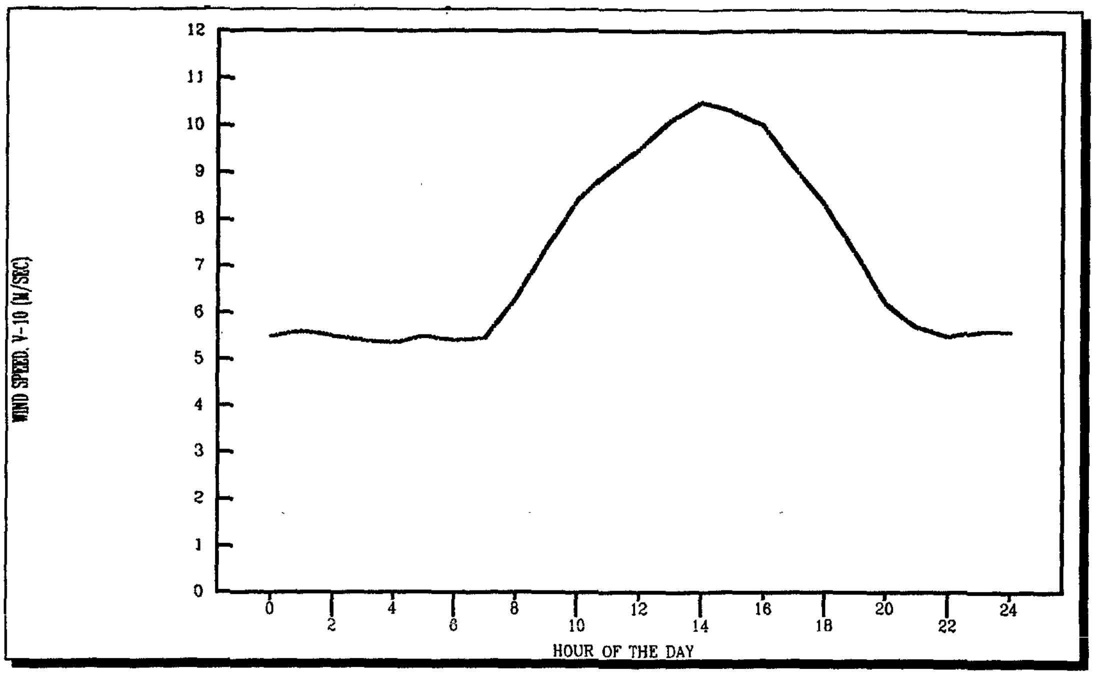

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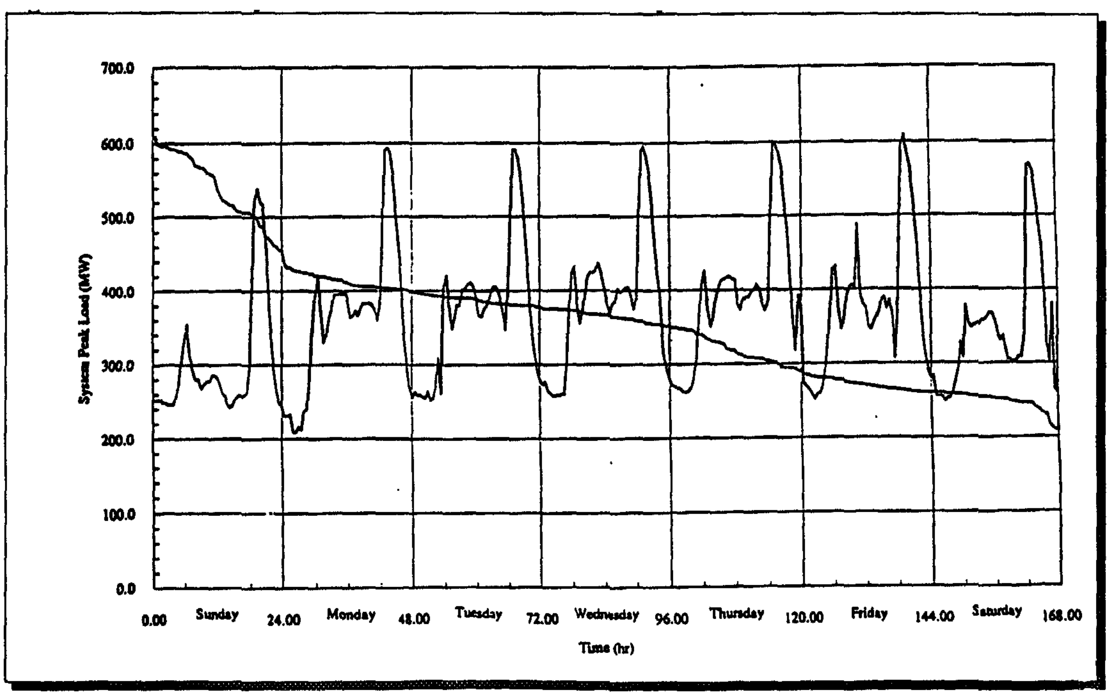

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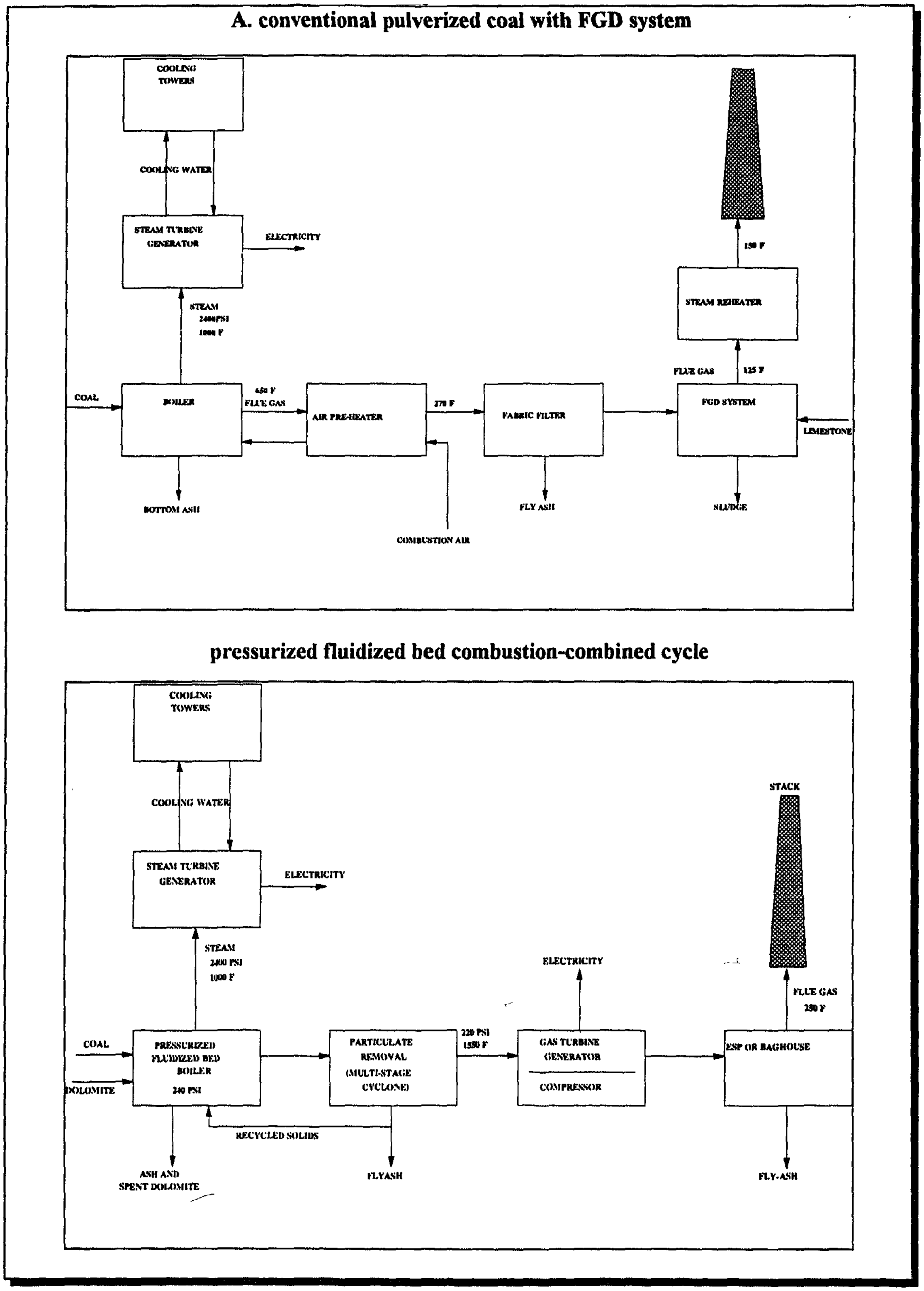

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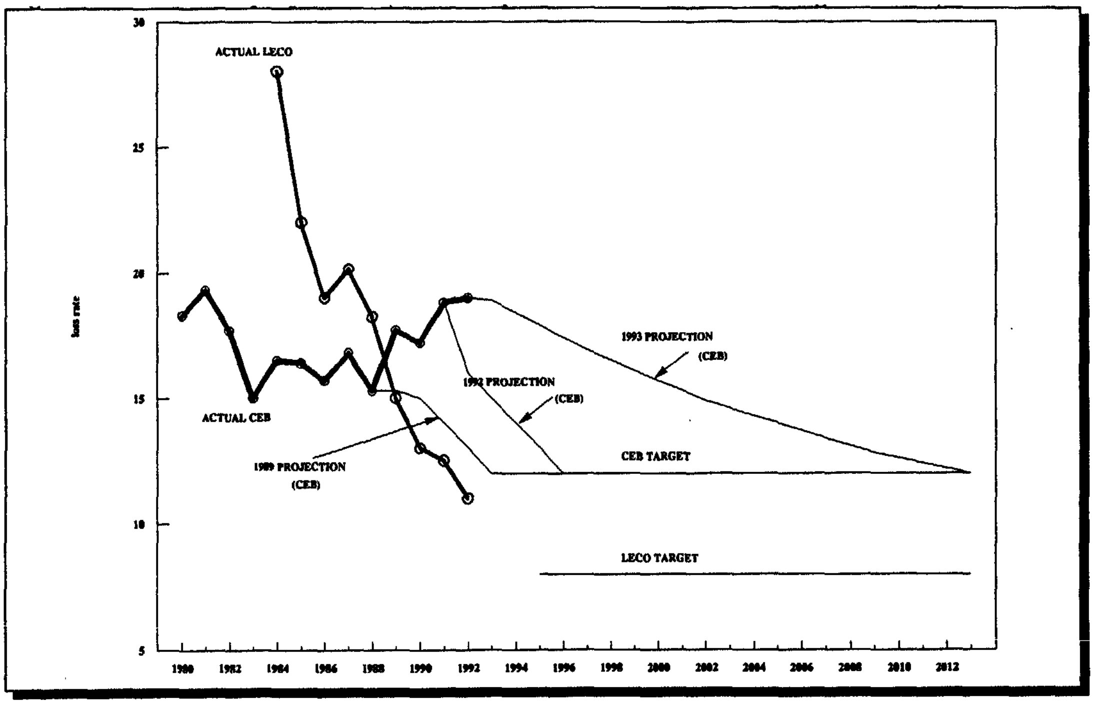

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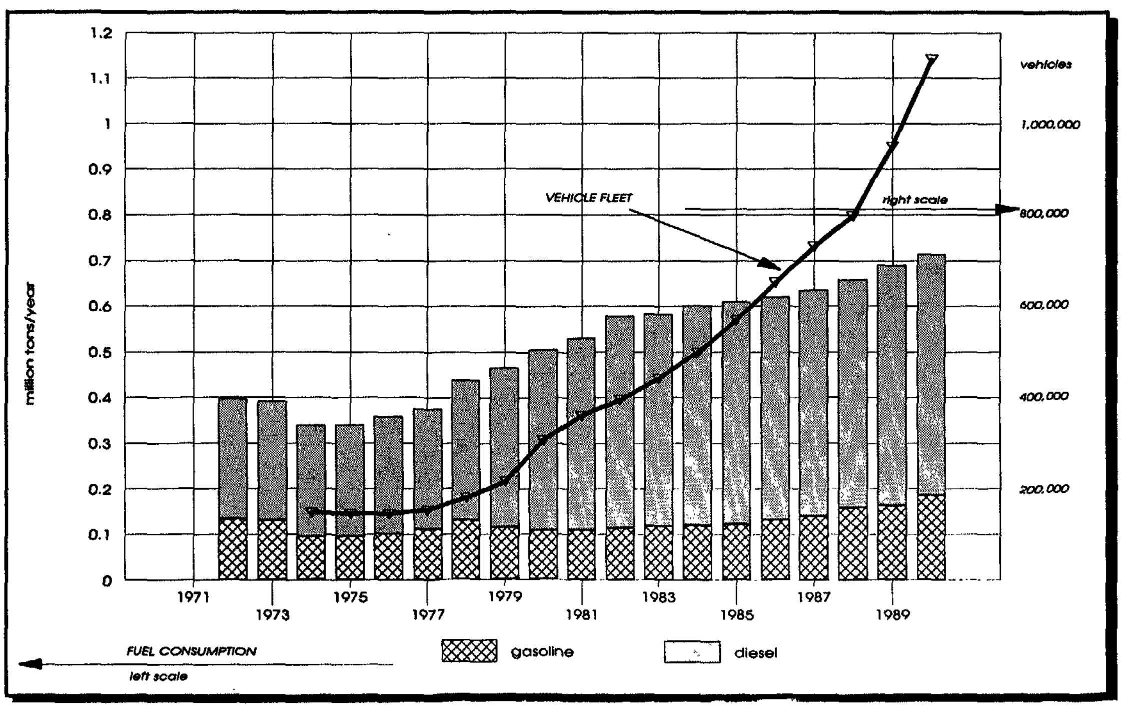

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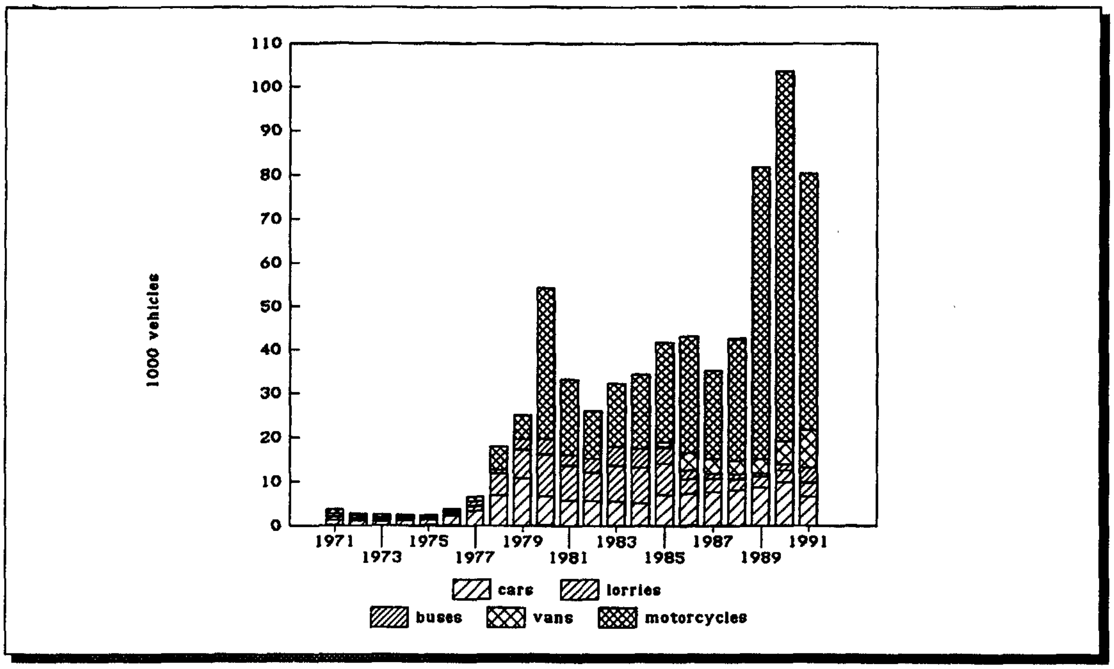

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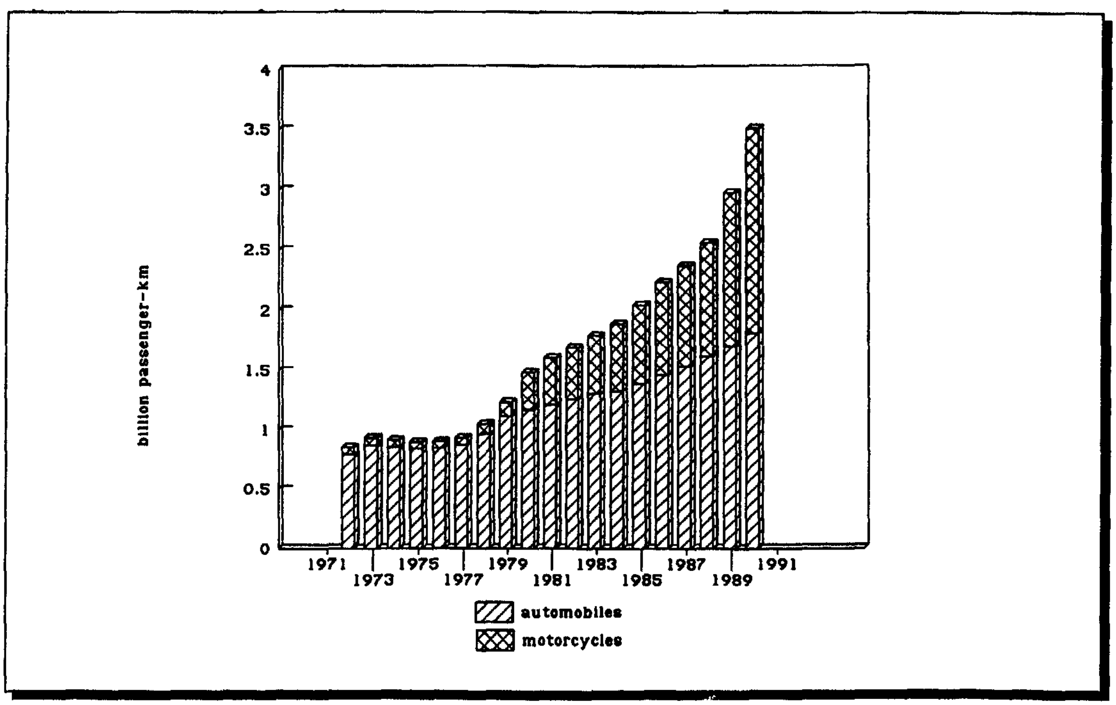

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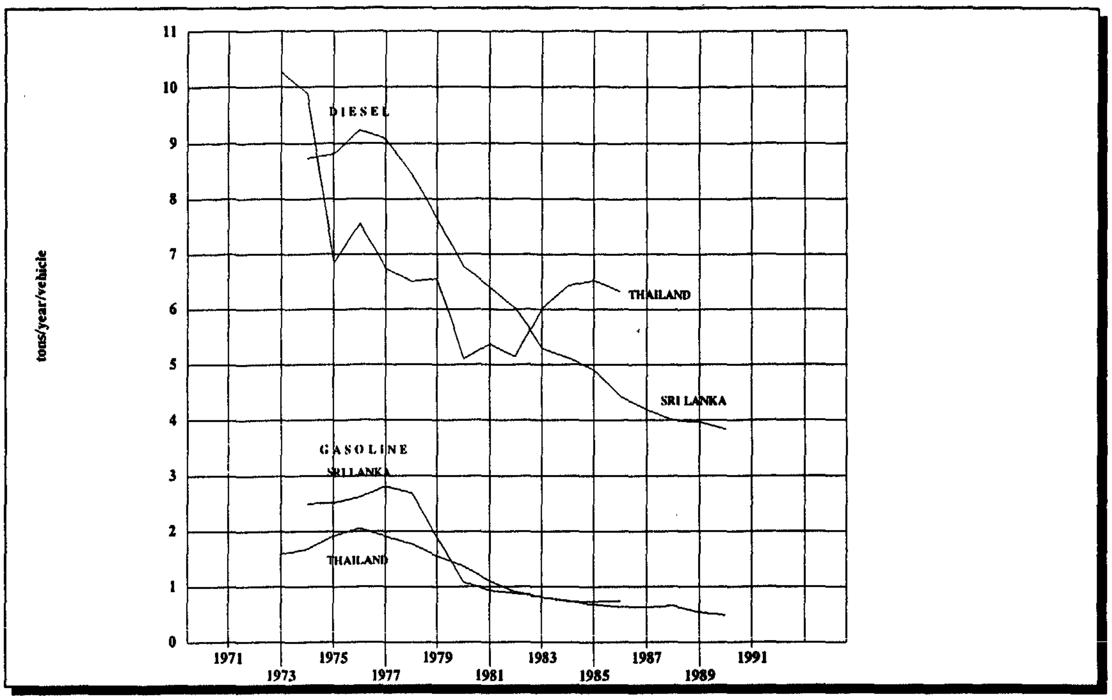

source: Thailand data from National Energy Administration, *Sectoral Energy Demand in Thailand*, Report to ESCAP Regional Energy Development Program, Nov. 1989, Annex C.

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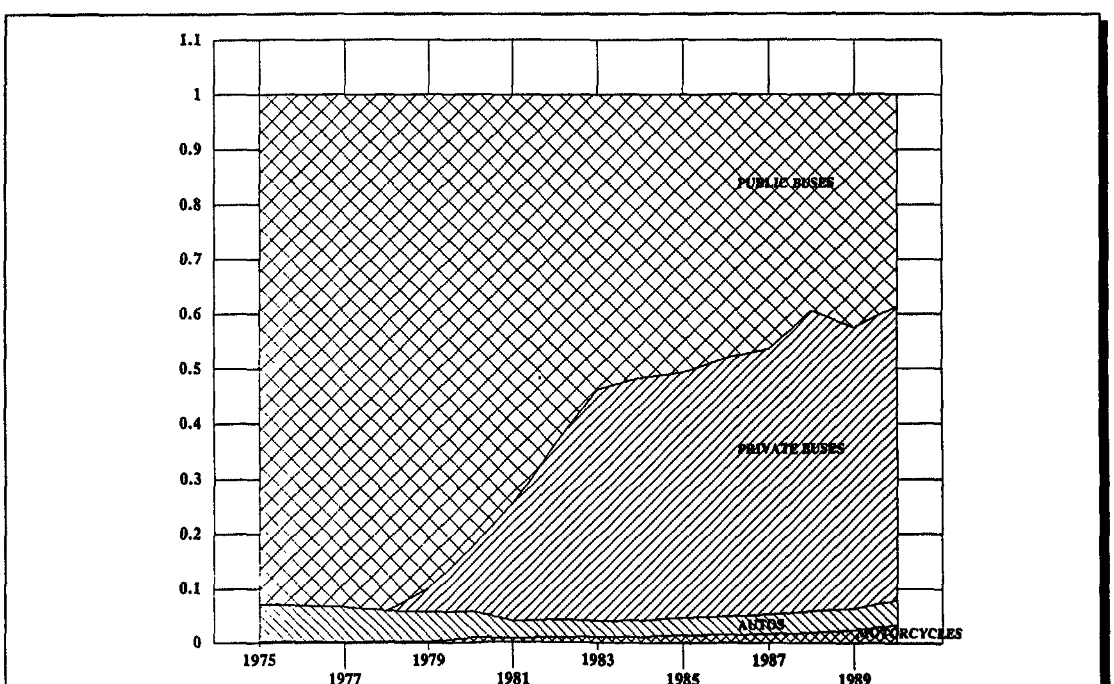

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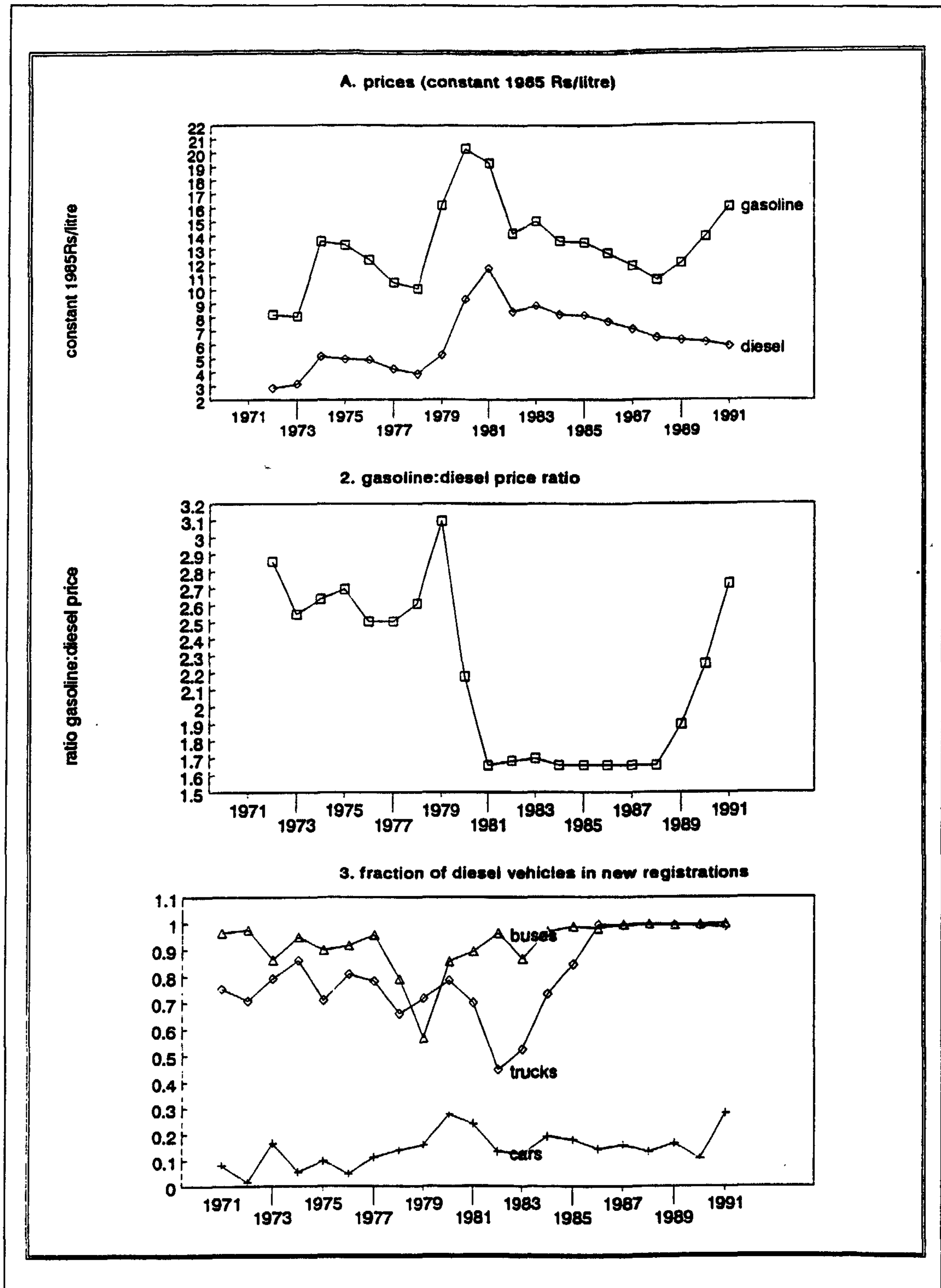

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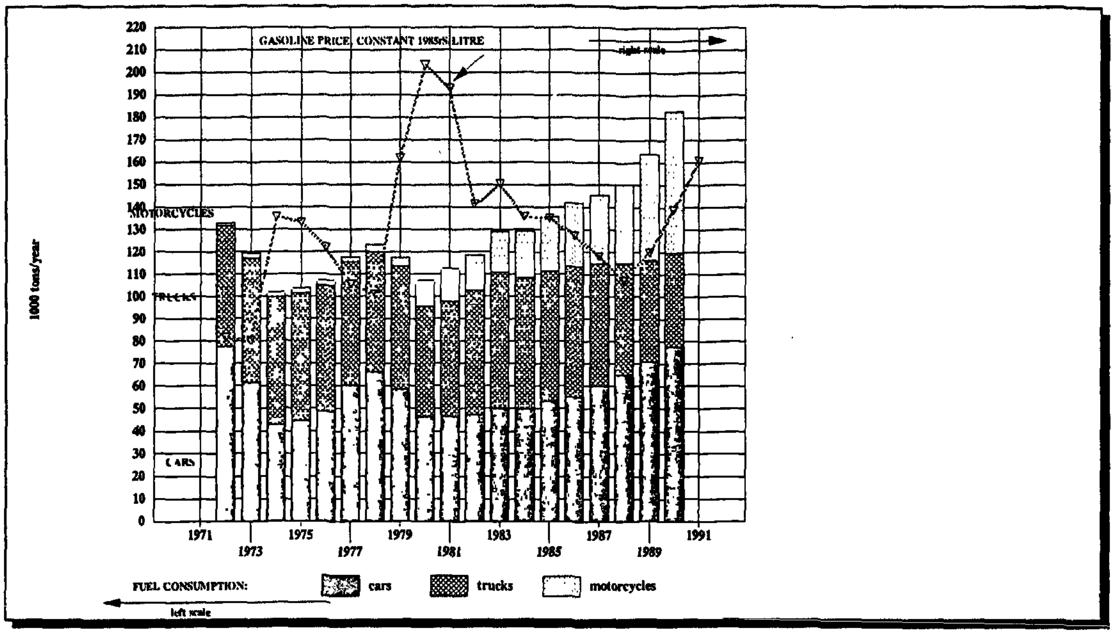

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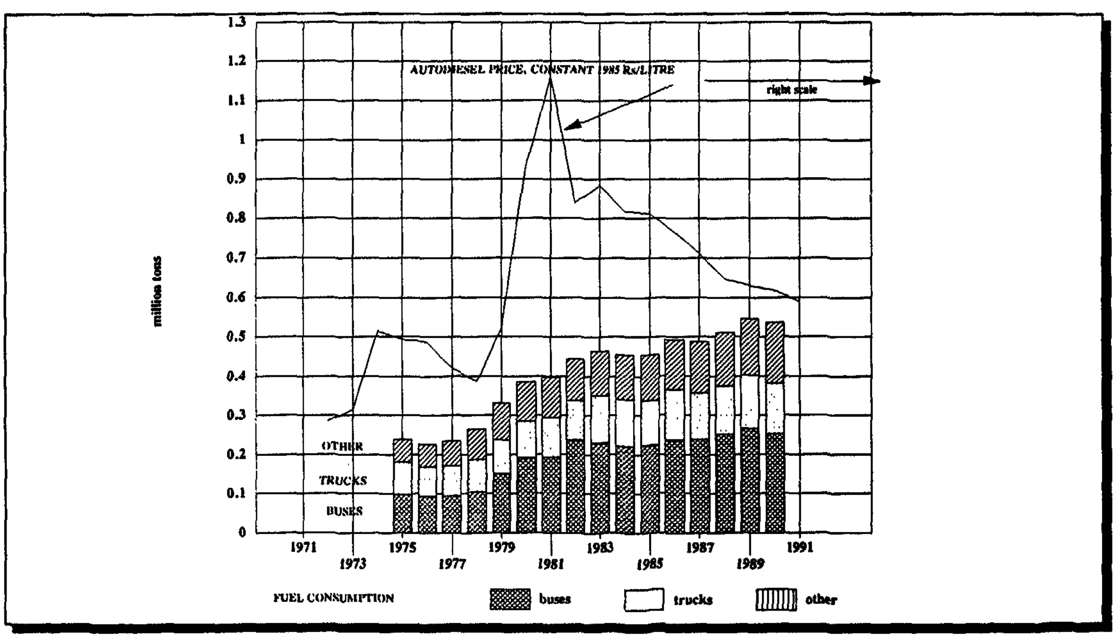

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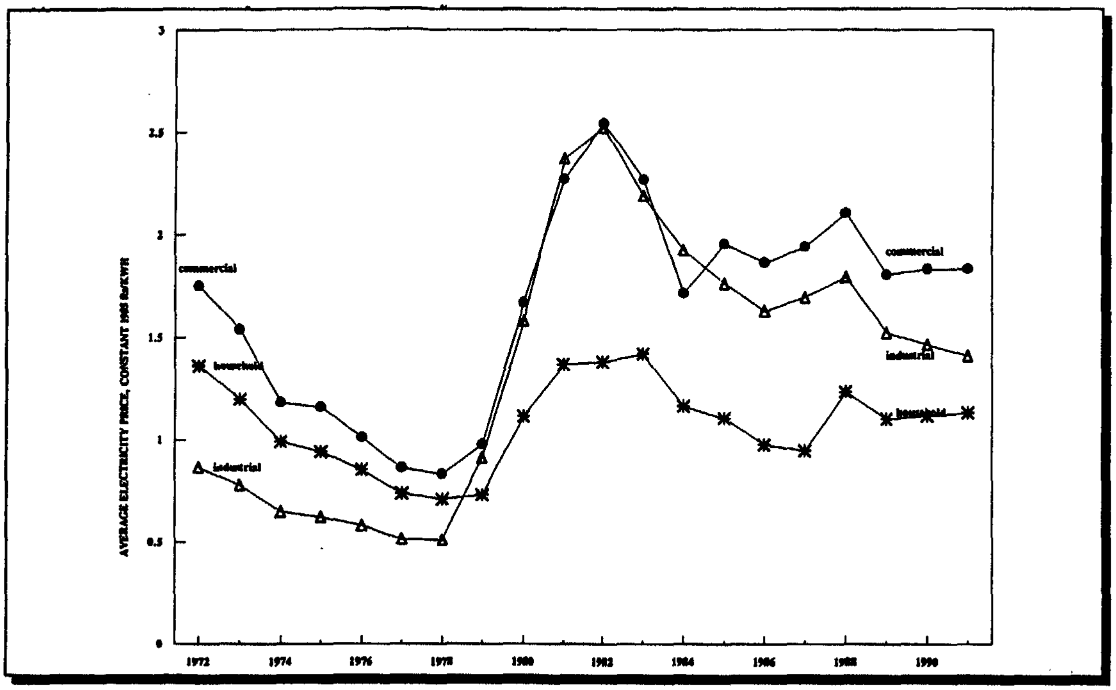

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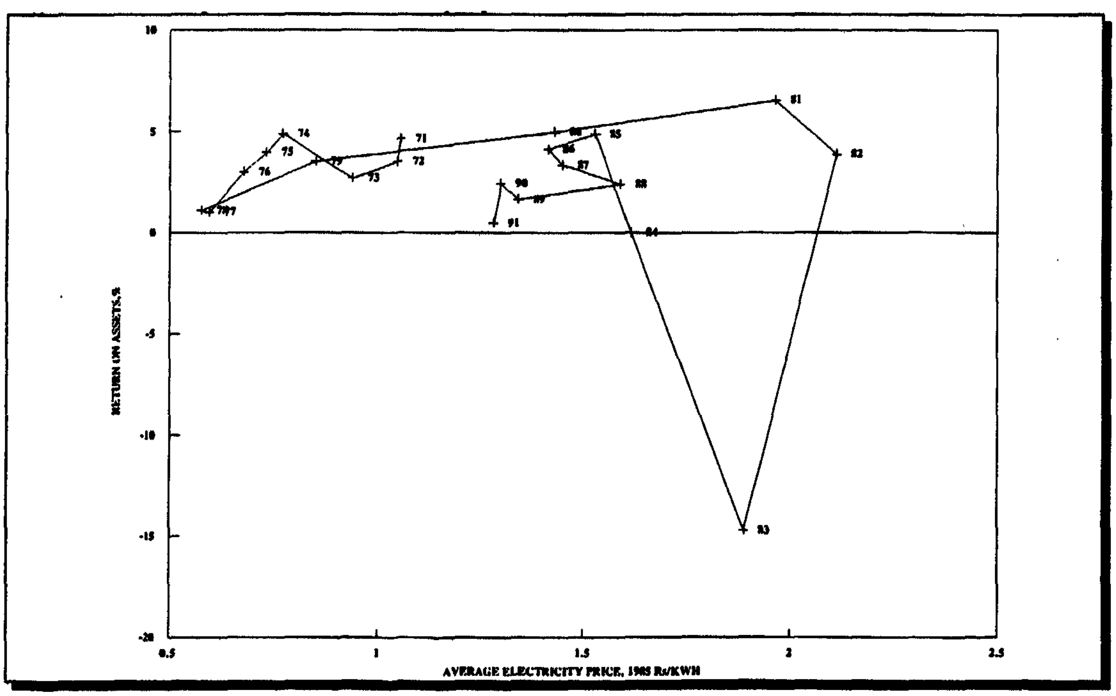

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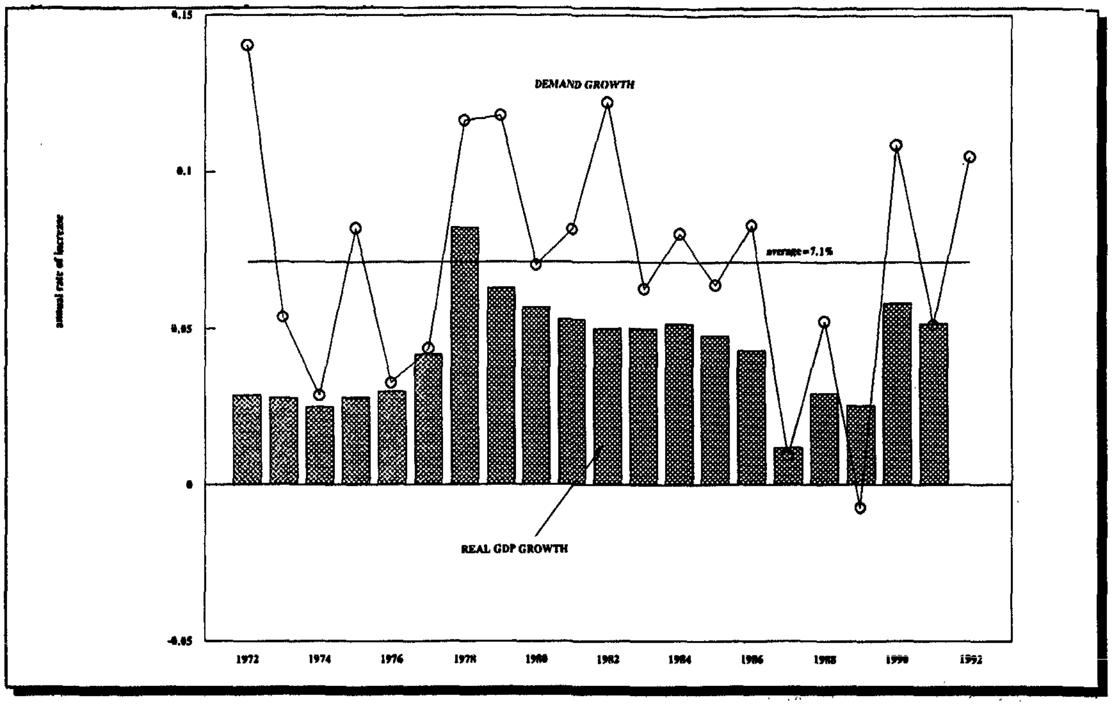

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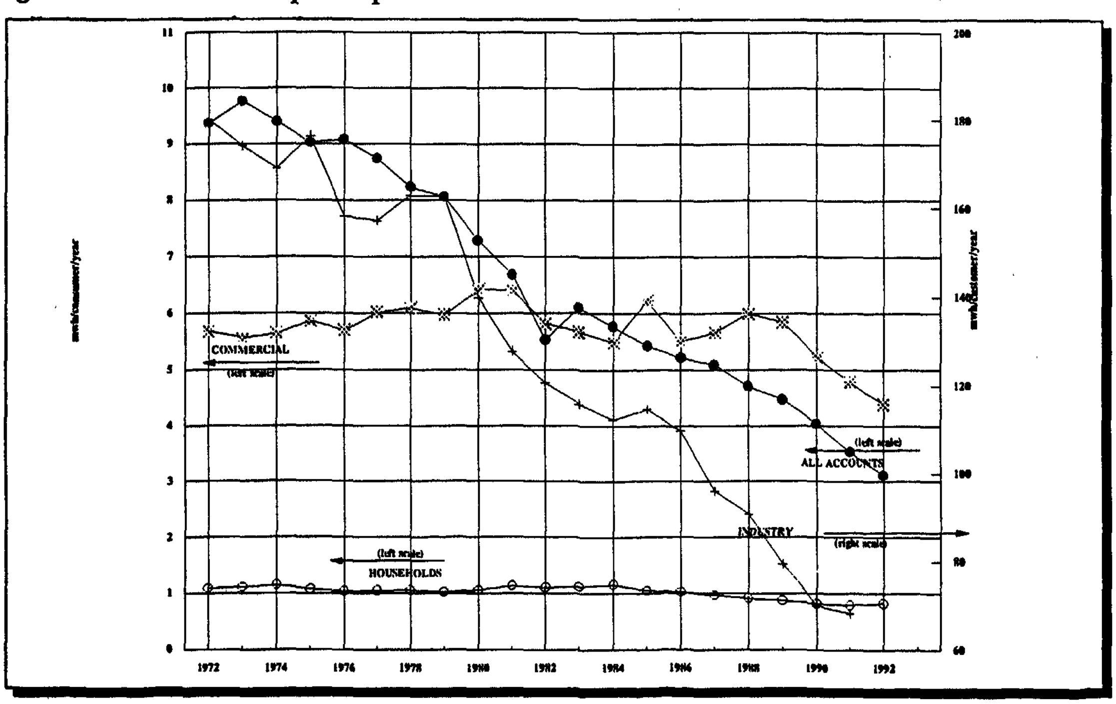

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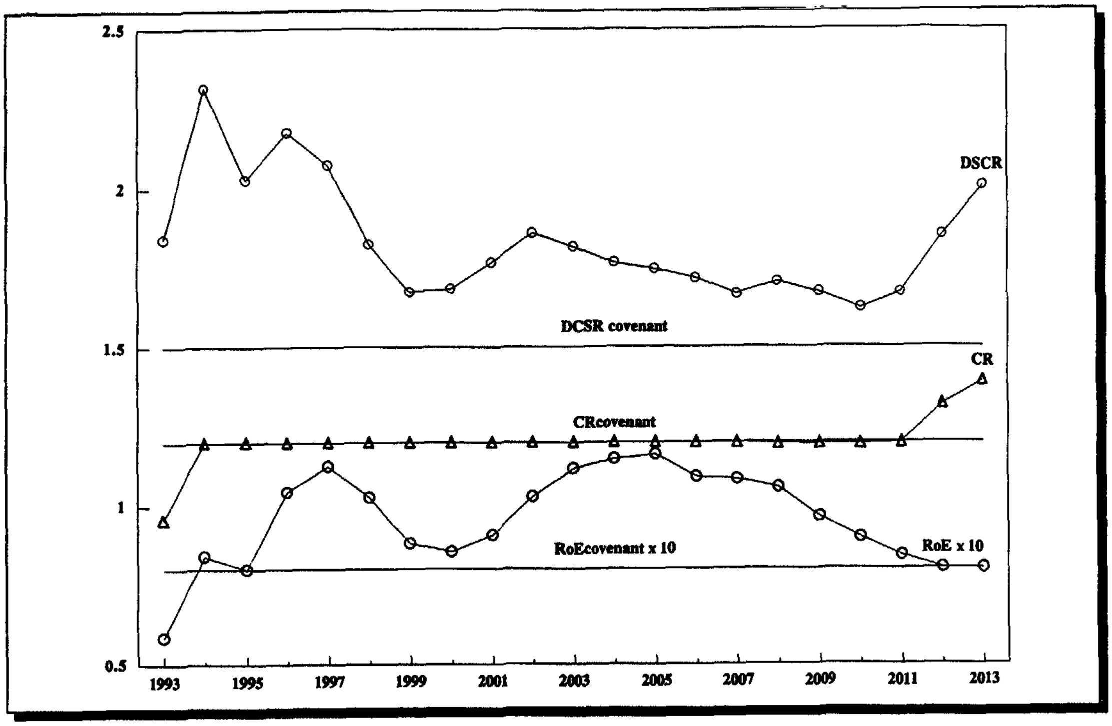

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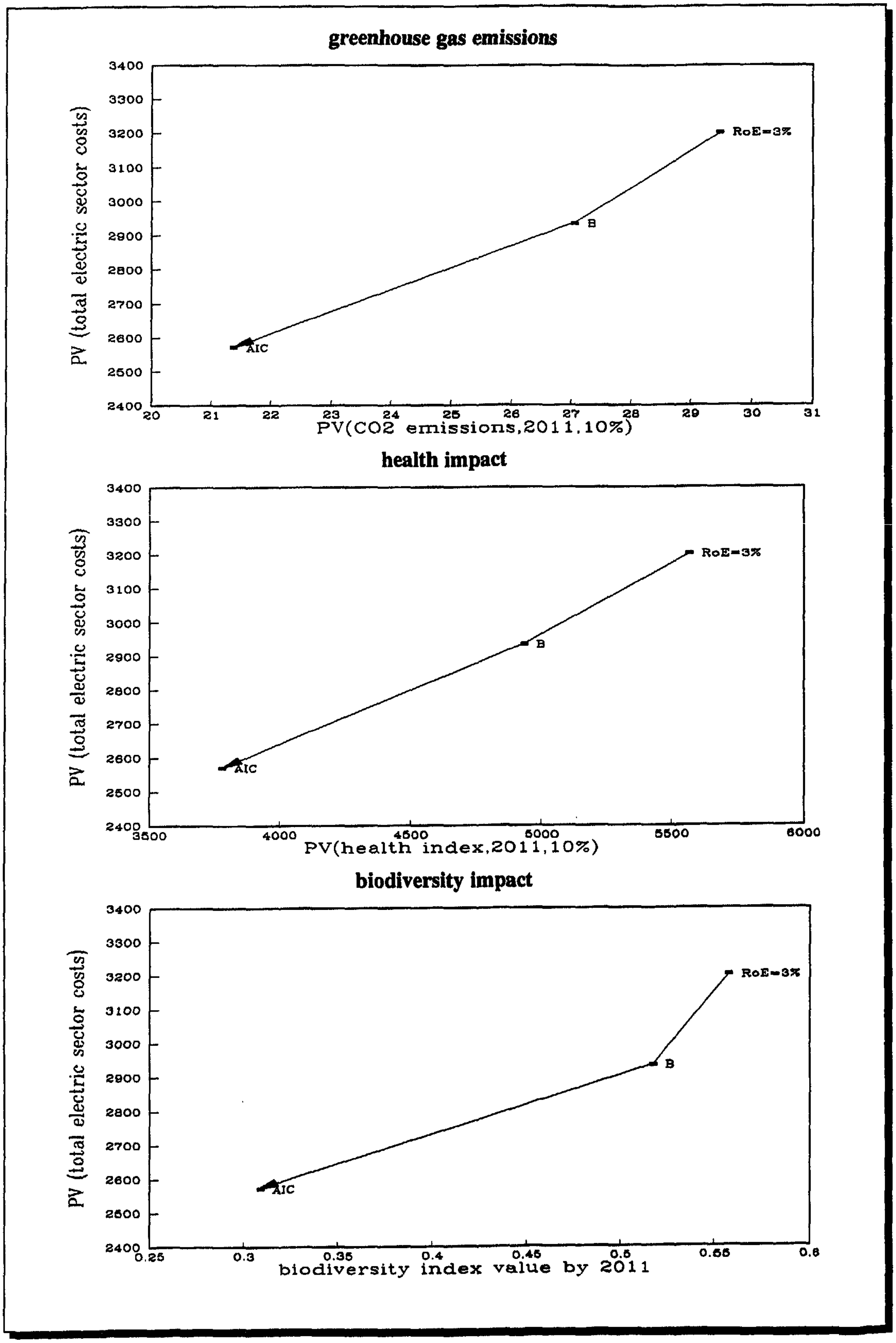

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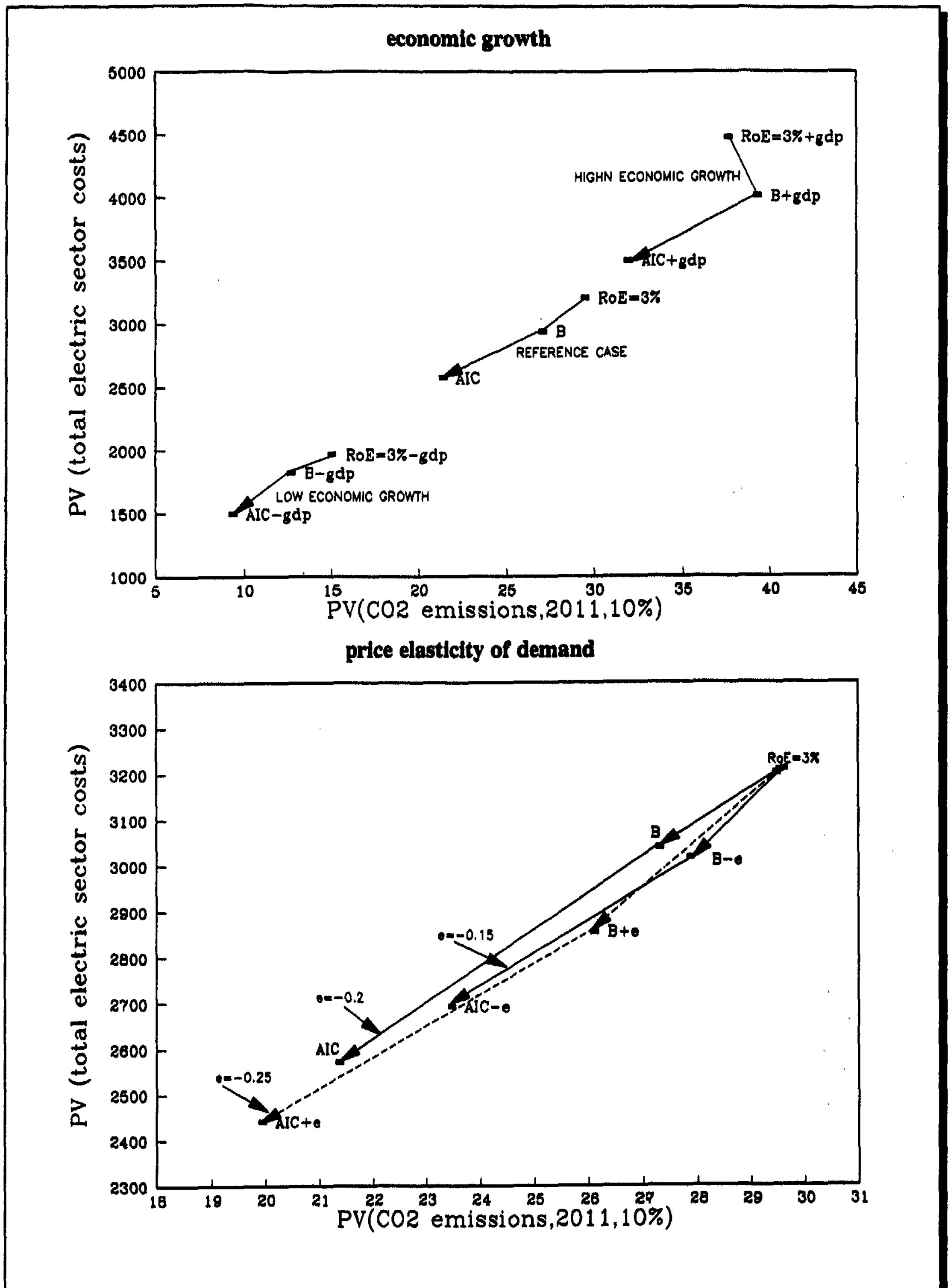

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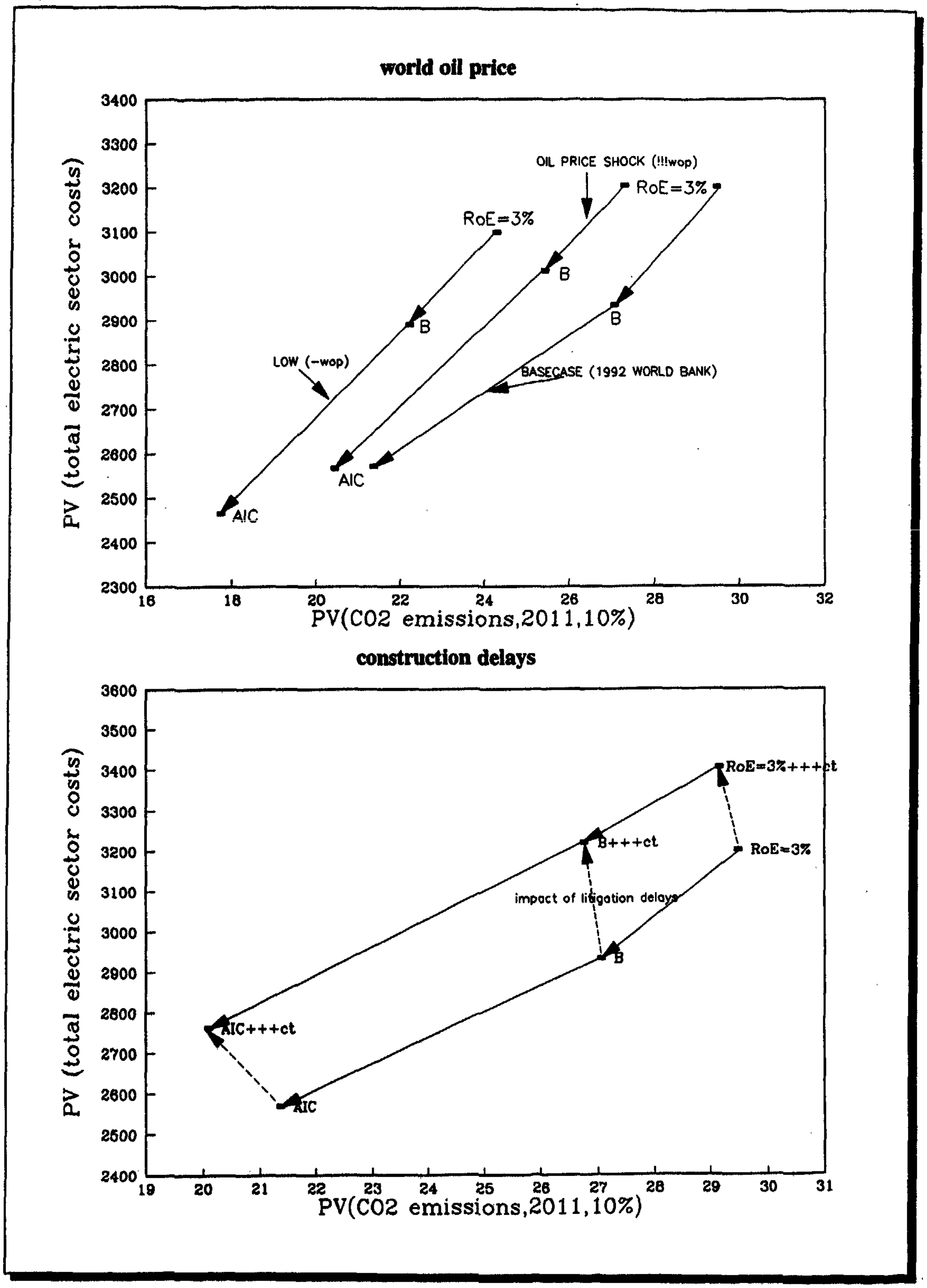


Figure 8–24. Likely Trends in Carbon Dioxide Emissions in Sri Lanka

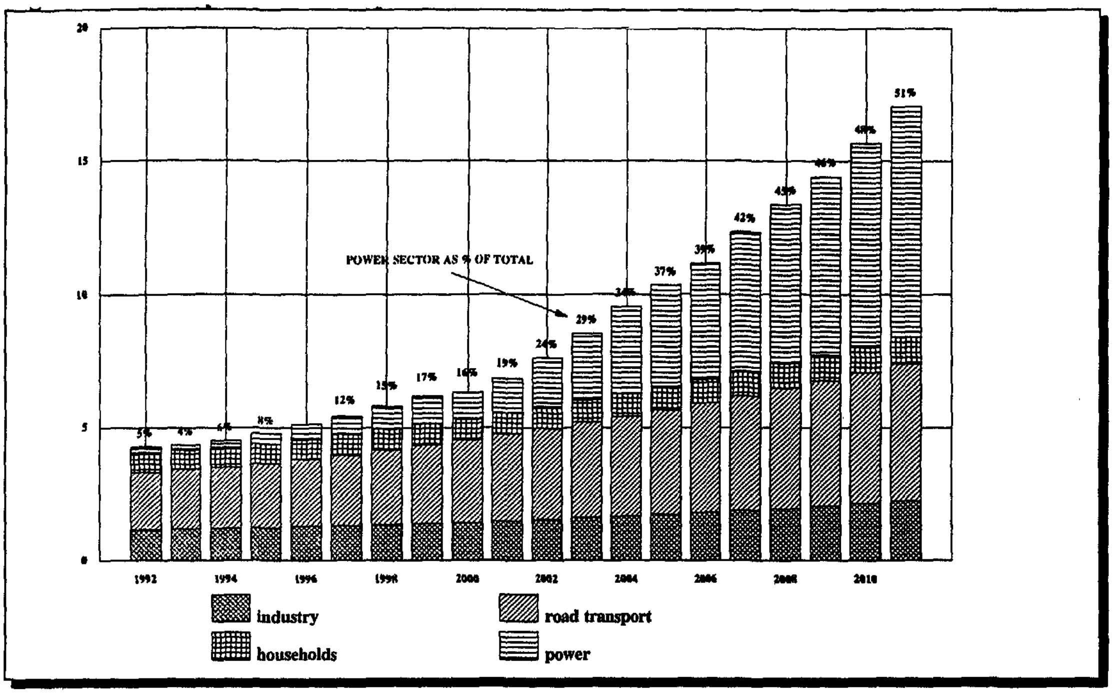


Figure 8–25. Definition of Tradeoff Curves

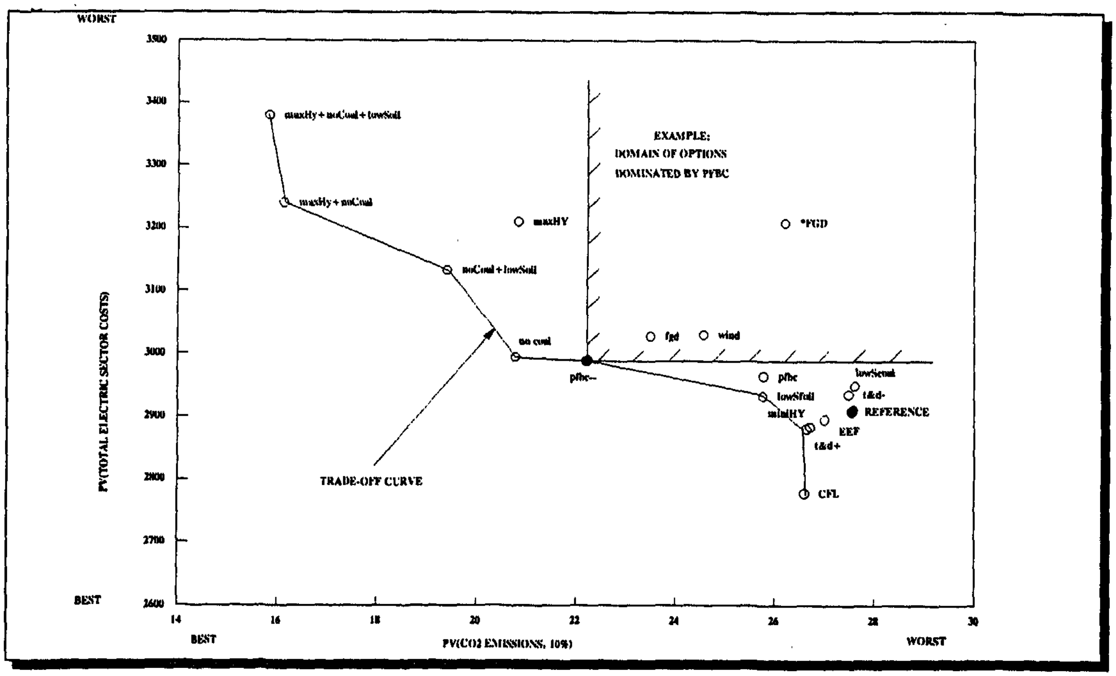


Figure 8–26. Win-Win Solutions

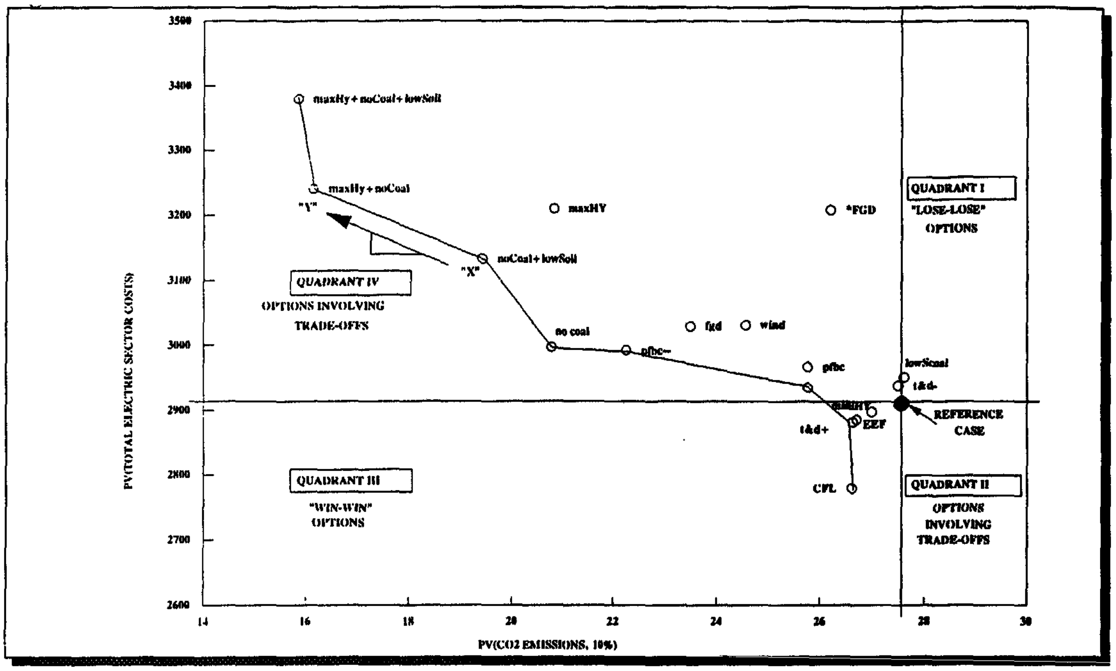


Figure 8–27. Tradeoff Curve for Sulfur Dioxide Emissions

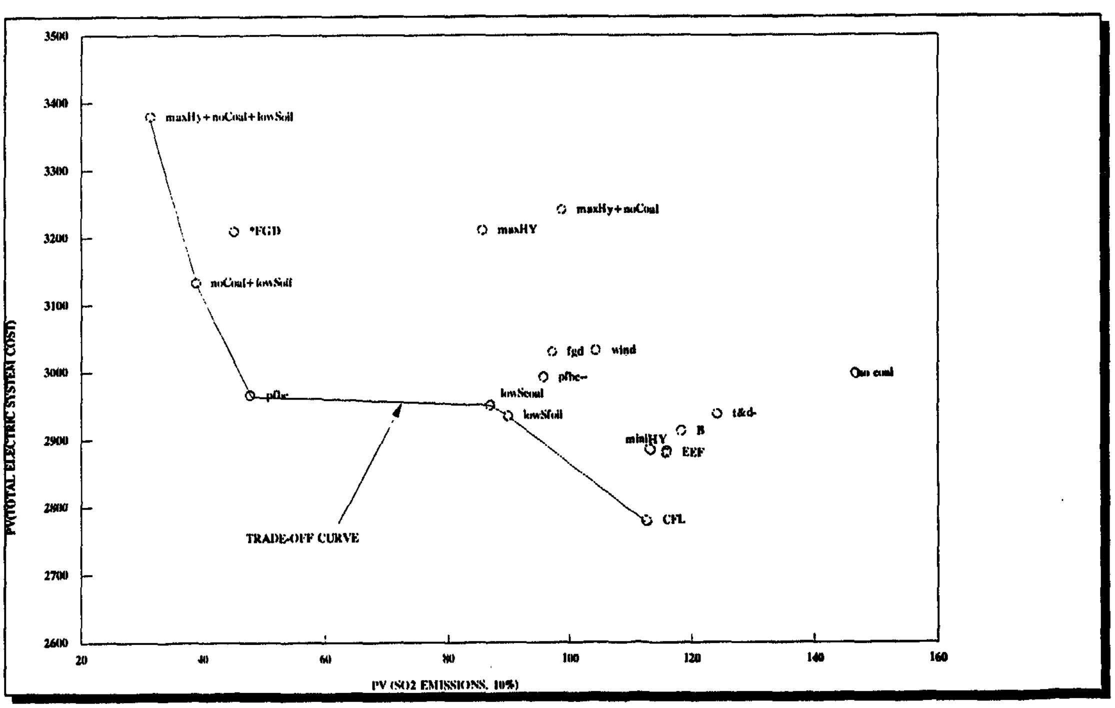


Figure 8–28. Tradeoff Curve for Health Impacts

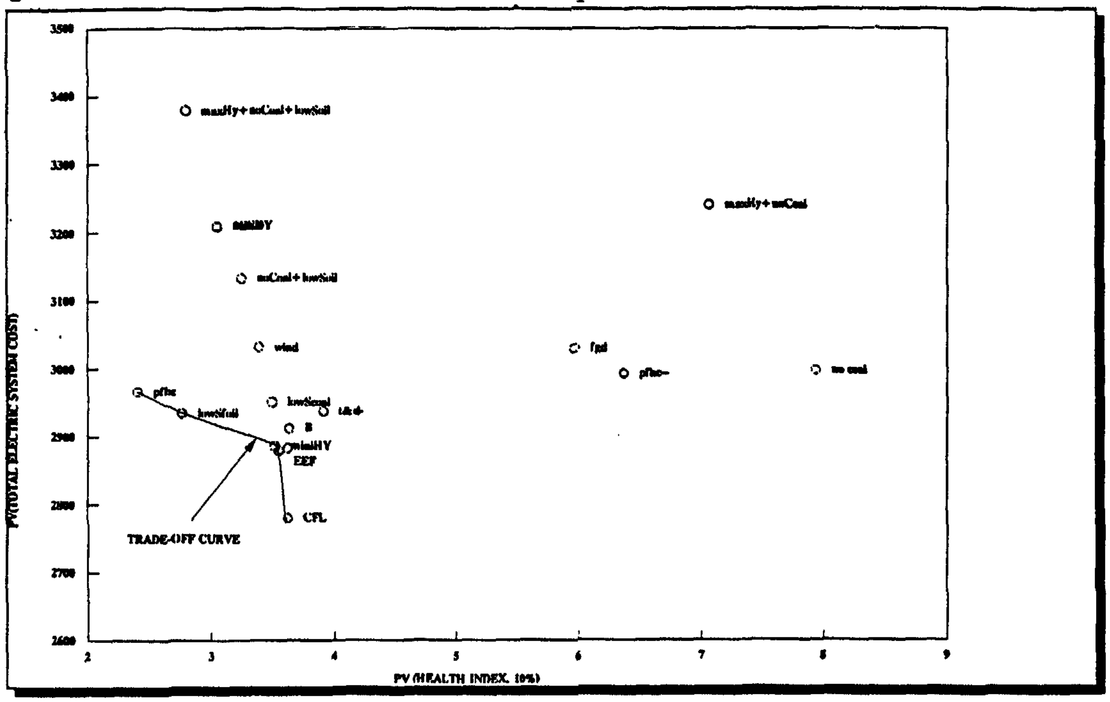


Figure 8–29. Time Trends in Health Impact Value

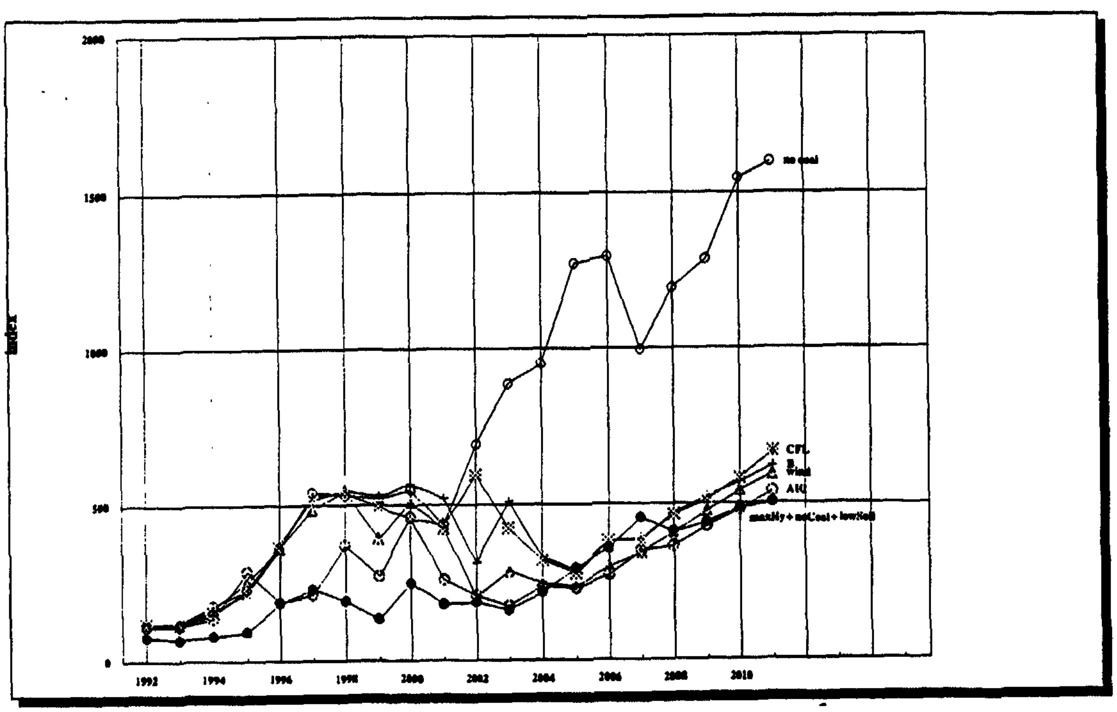


Figure 8–30. Tradeoff Curve Between Global and Local Impacts

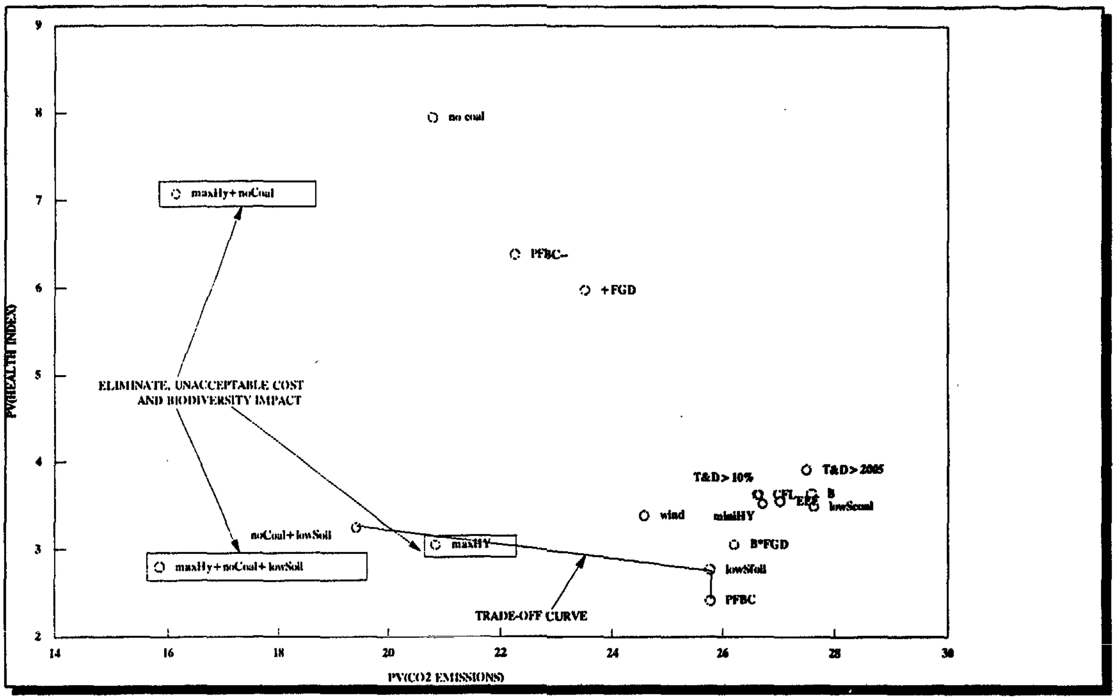


Figure 8–31. Comparison of Price Options Compared with Non-Price Options

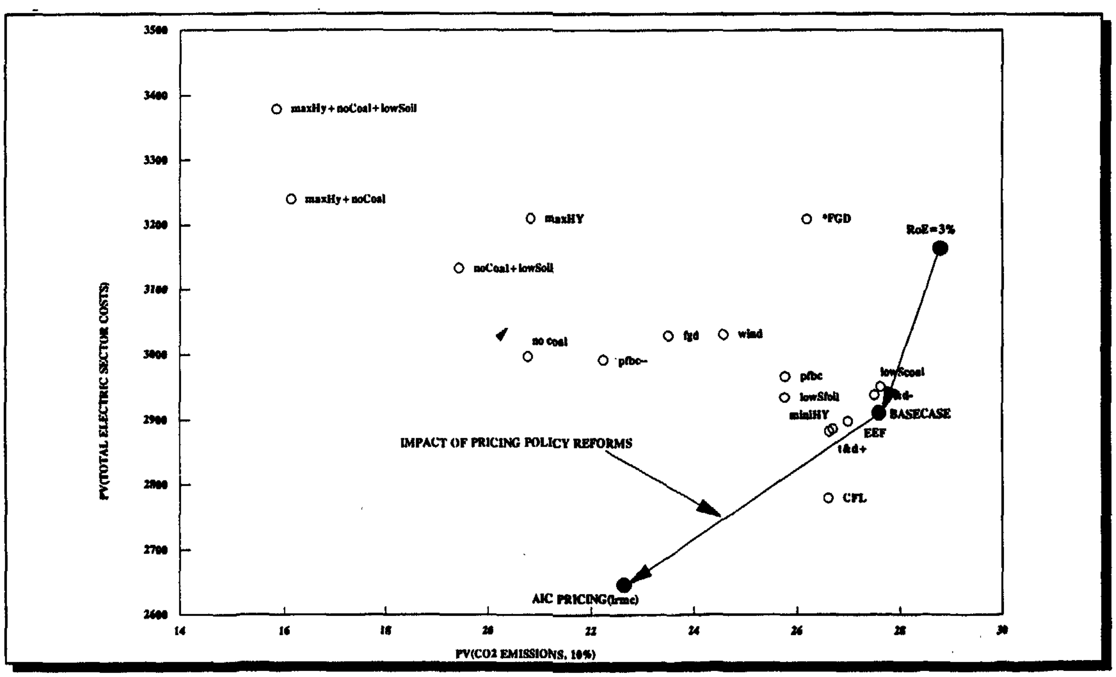


Figure 8–32. Impact of an Externality Tax

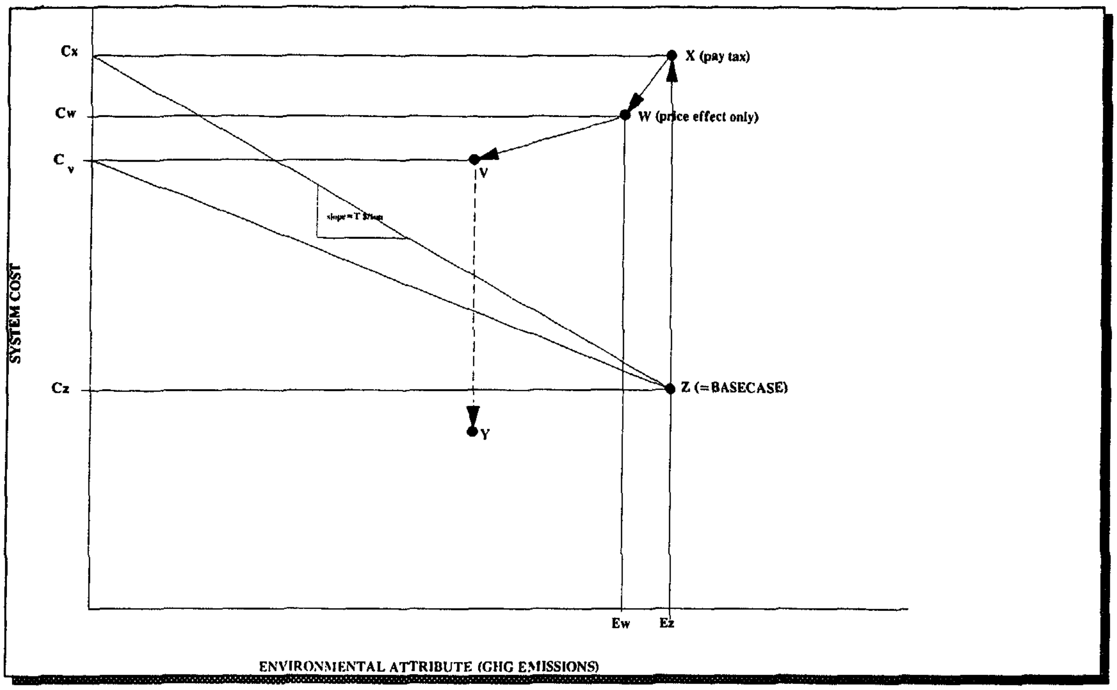


Figure 8–33. Impact of Externality Taxes

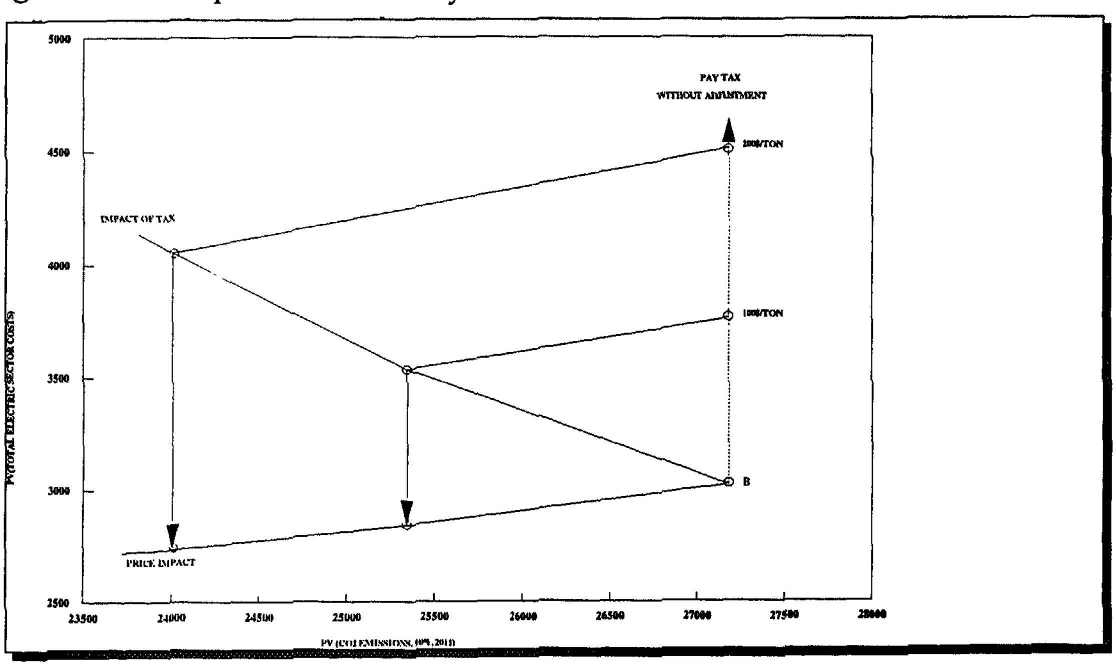


Figure 8–34. Impact of Carbon Taxes

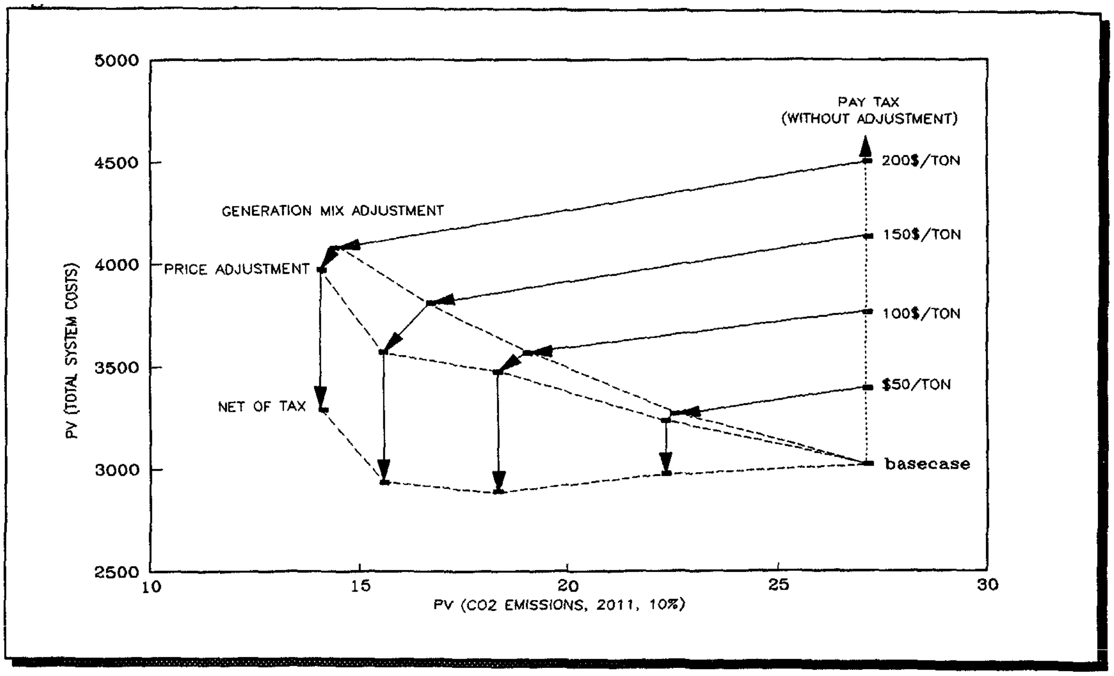


Figure 8–35. Comparison of Carbon and Externality Taxes

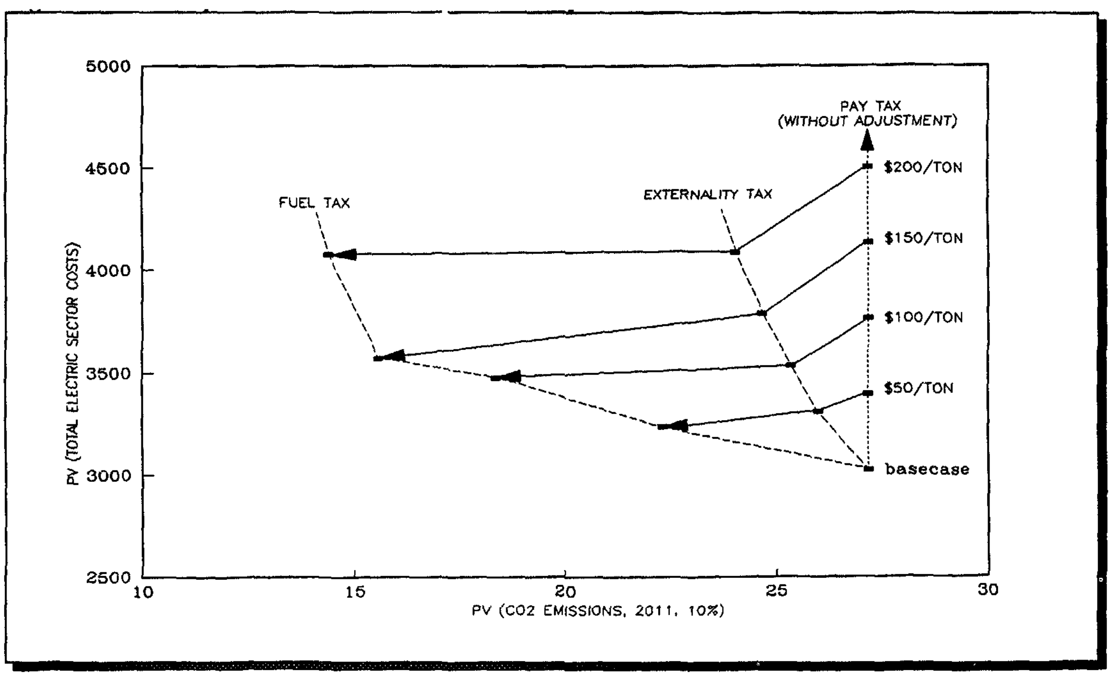


Figure 8–36. Government Revenue from the Electric Sector

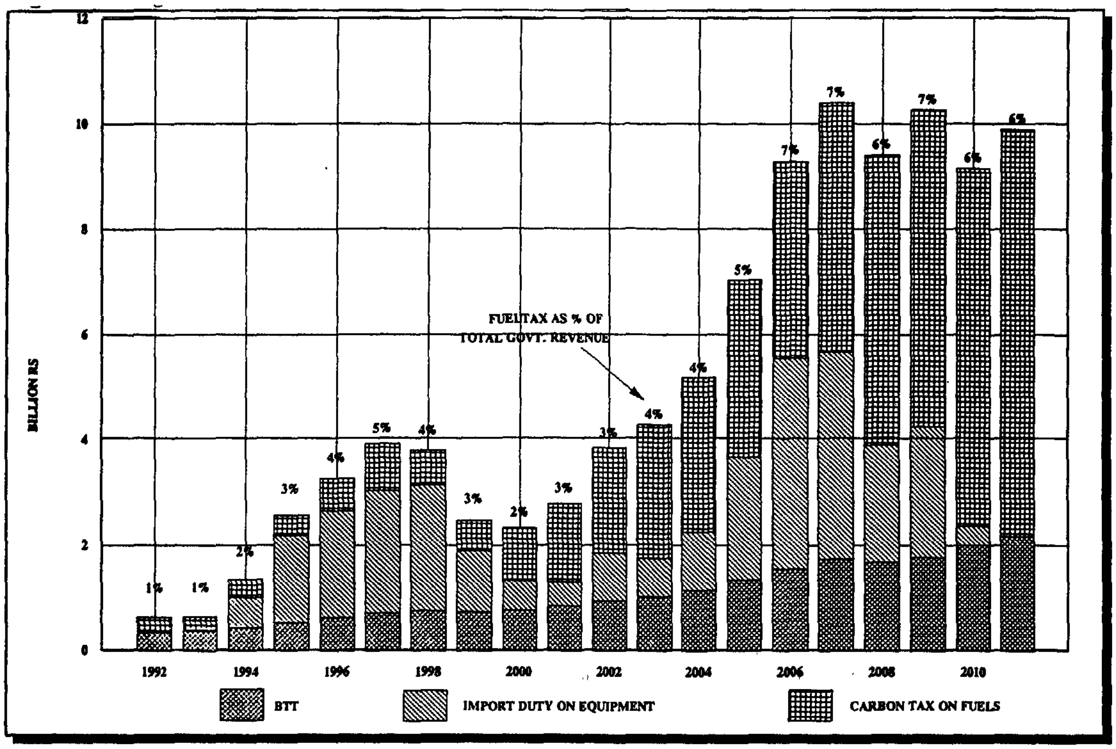


Figure 8–37. TradeOff Curve For Transportation Sector Options

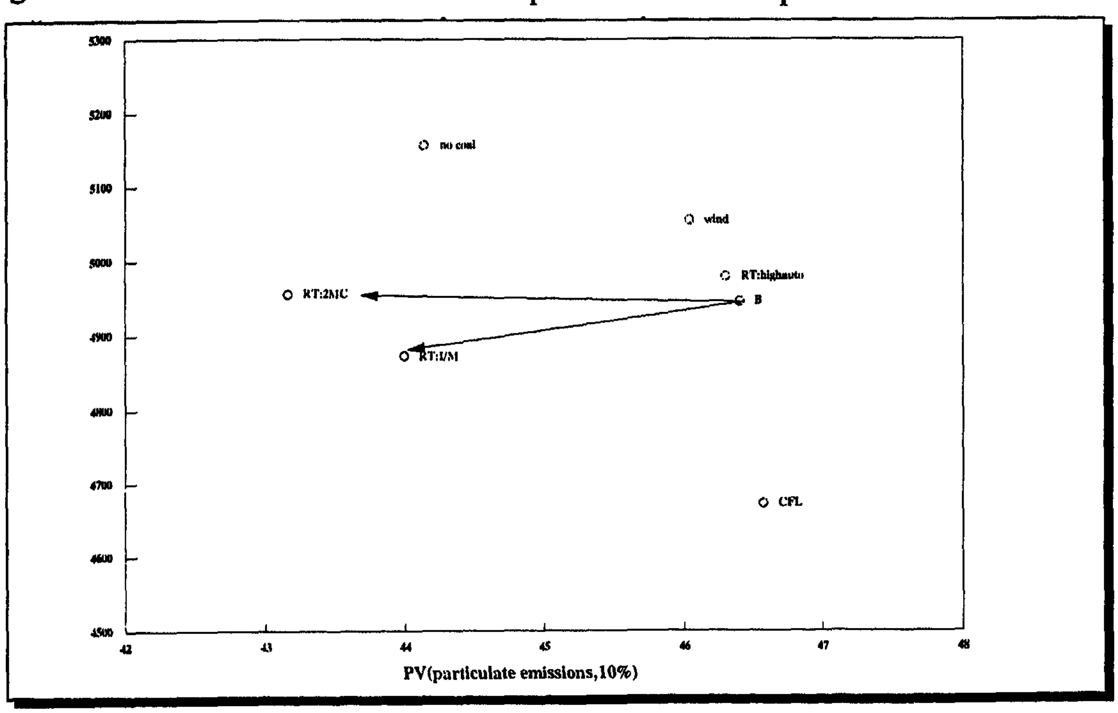


Figure 8–38. Tradeoff Curve for Particulates

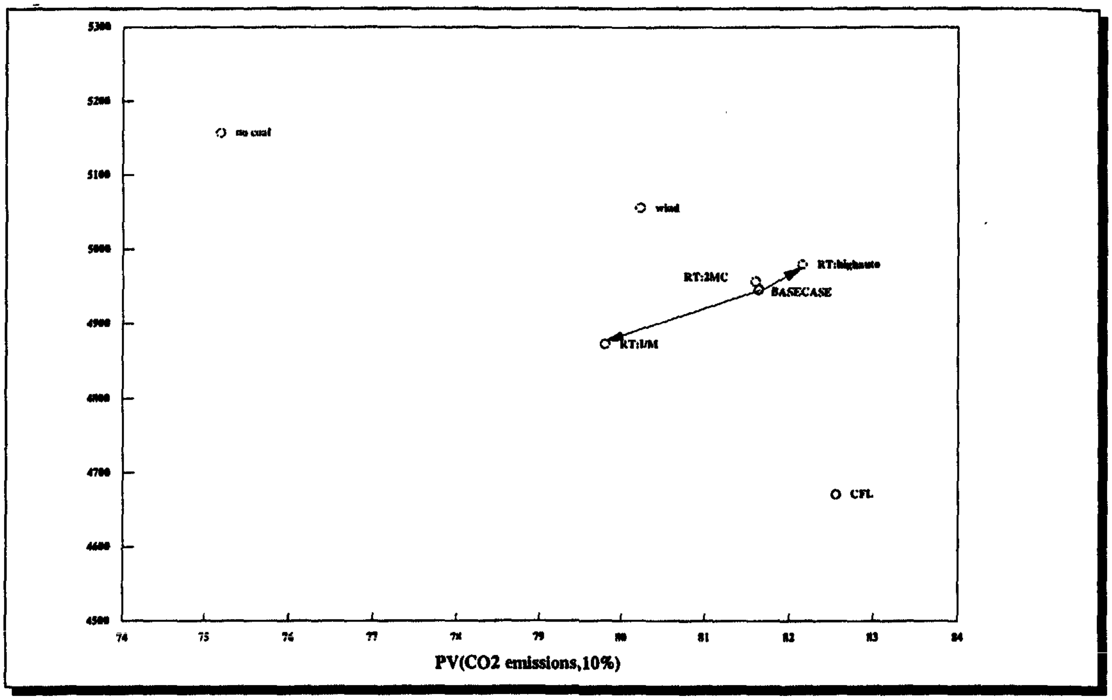


Figure 8–39. Optimum Portfolio for GHG Reduction

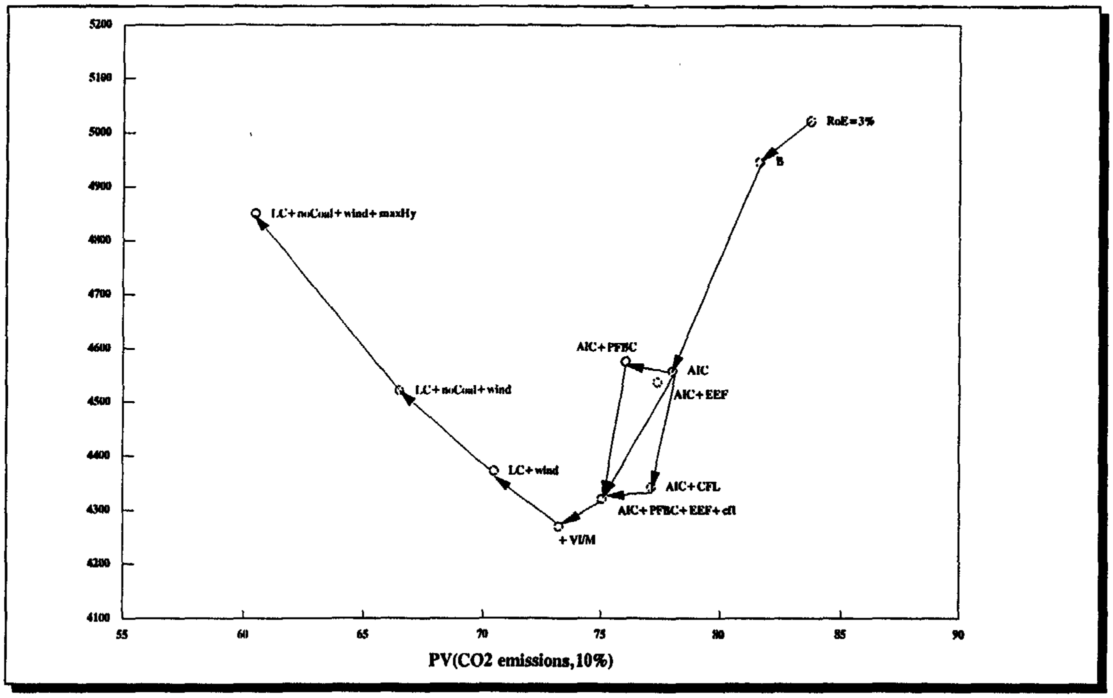


Figure 8–40. Cost Curve for GHG Emission Reductions

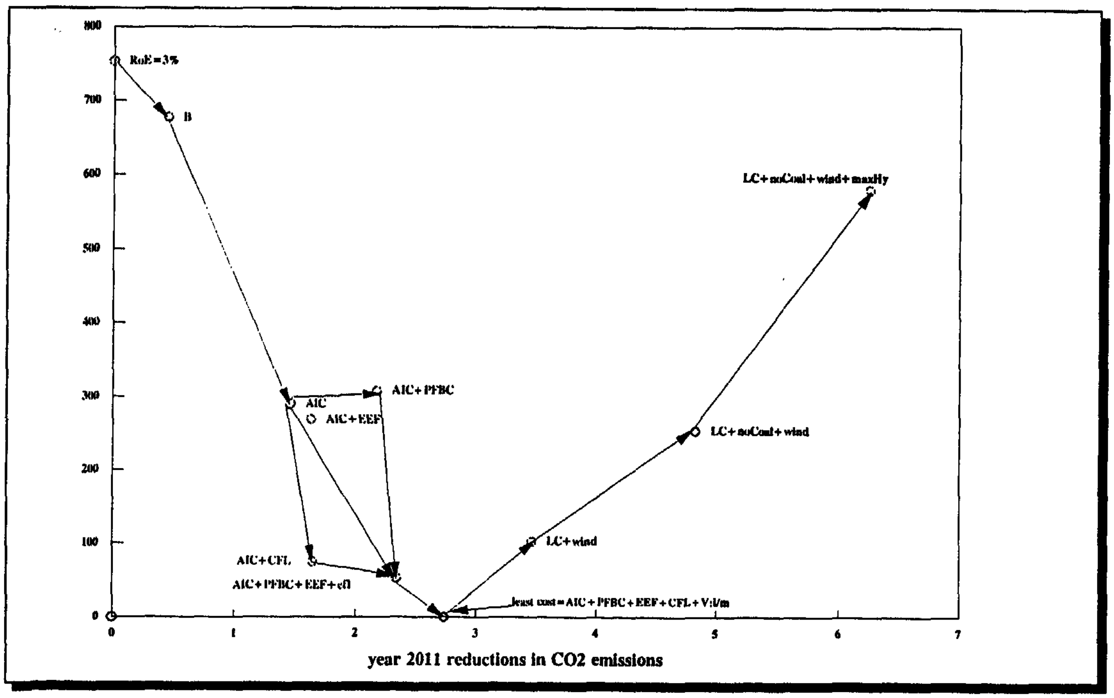


Figure 8–41. Comparison of Sri Lanka Results with Other Countries

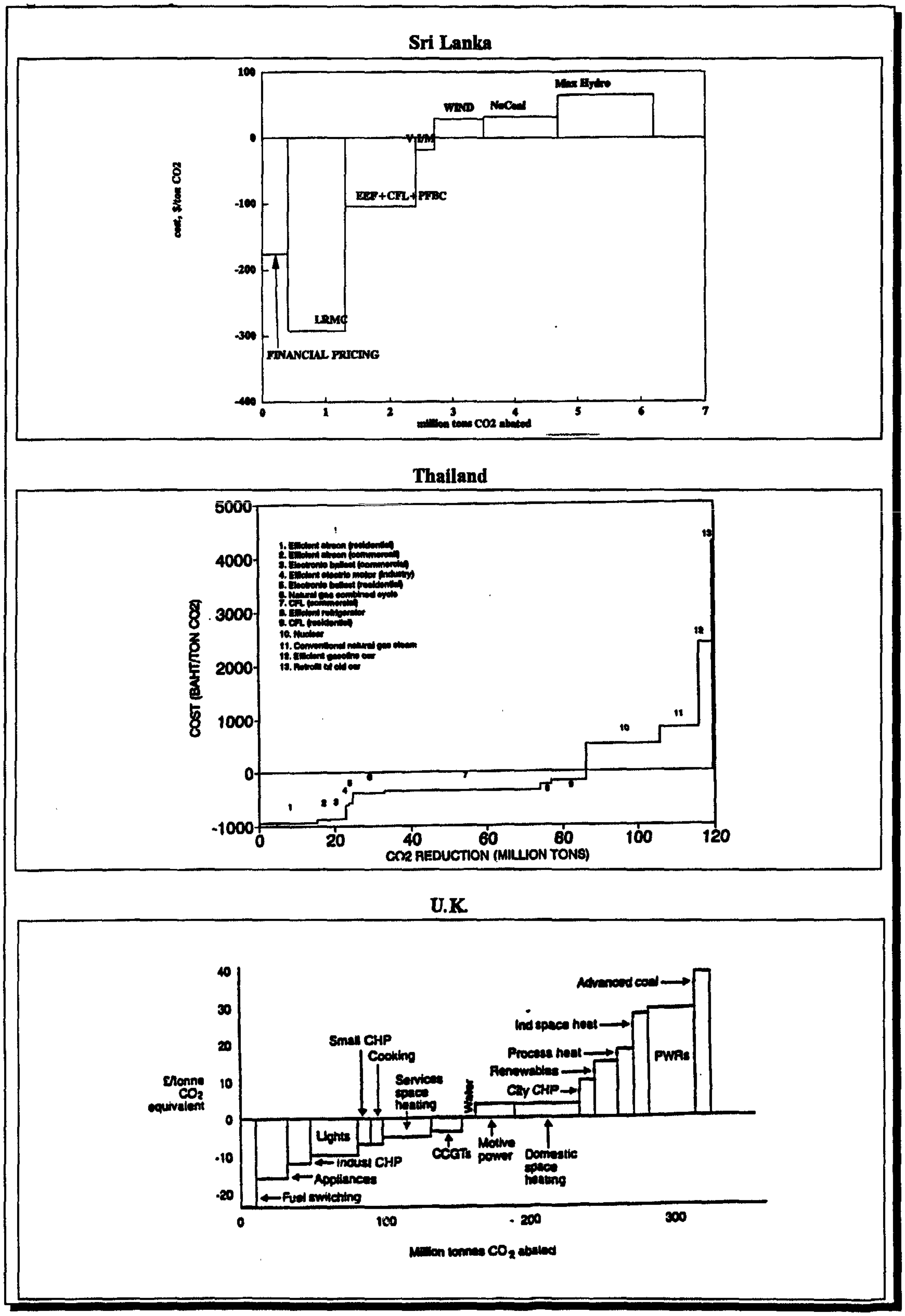
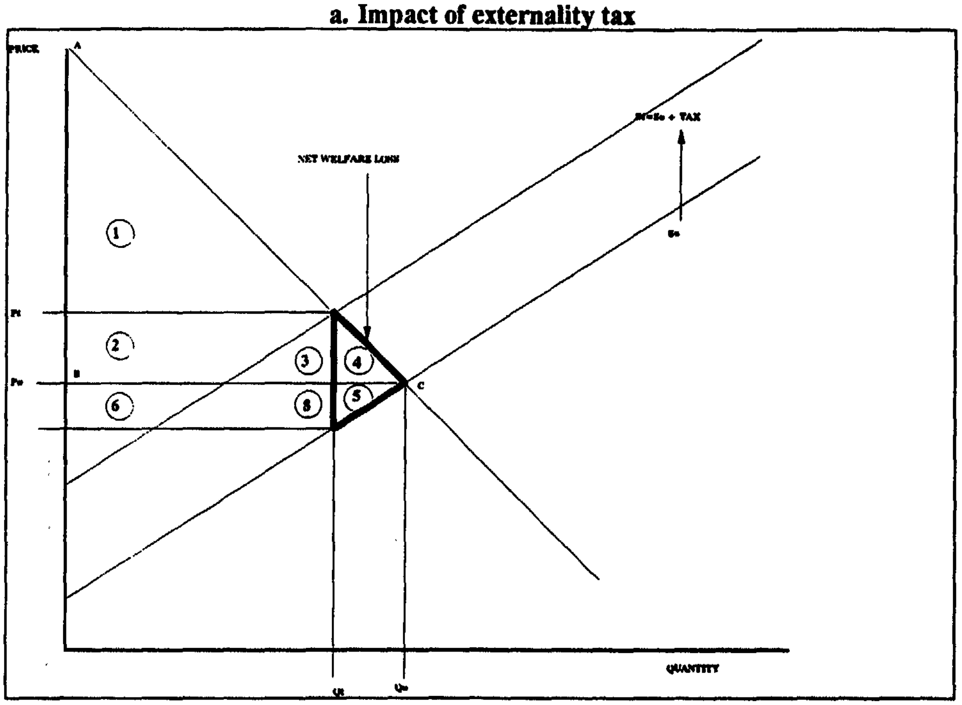


Figure 8–42. Welfare Loss

a. Impact of externality tax



b. Impact of wind energy

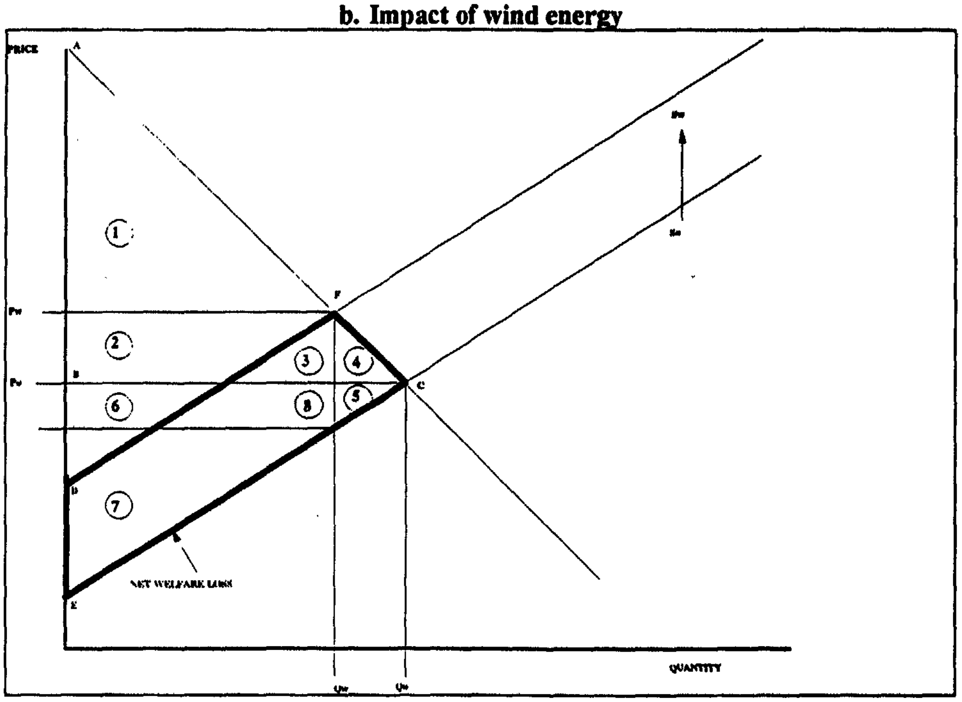


Figure 8–43. Impact of the Price of Unserved Energy: Reference Case

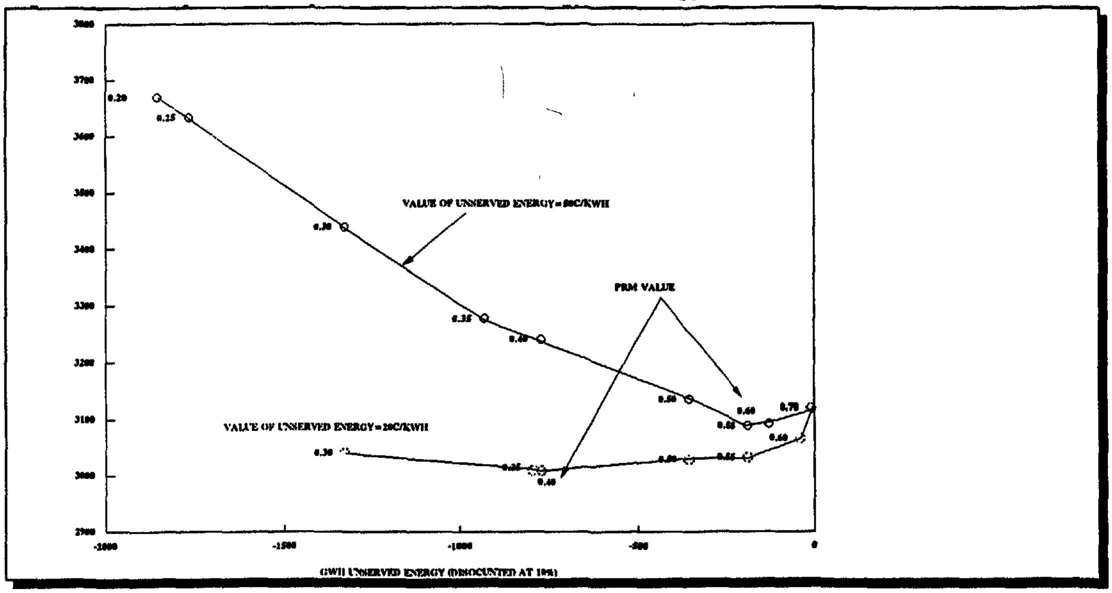


Figure 8–44. Optimum Level of Unserved Energy for the Wind Energy Scenario

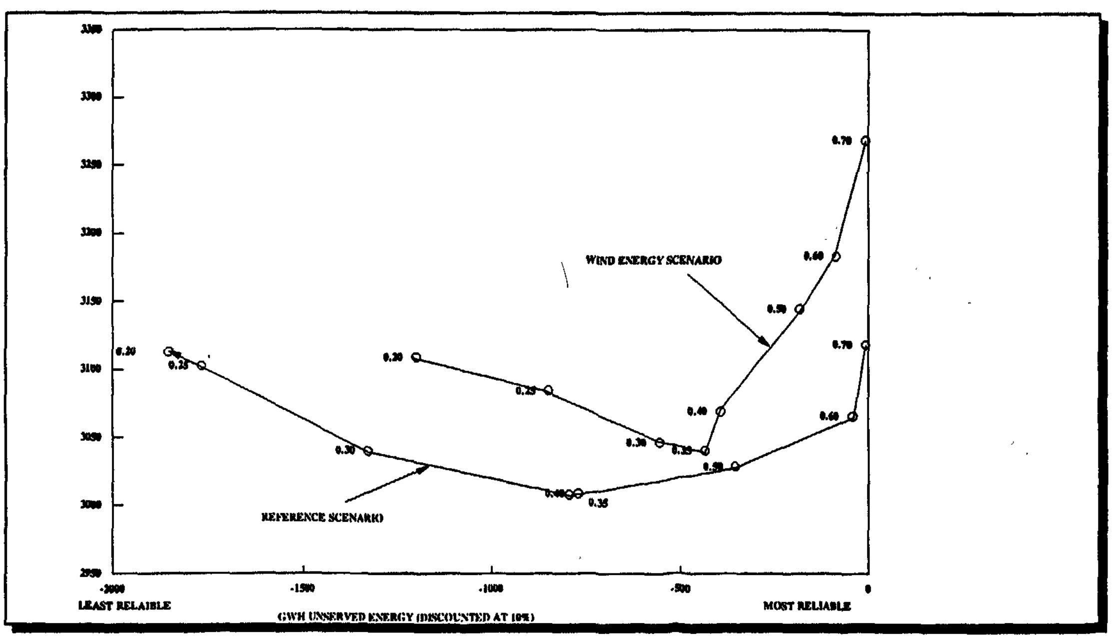


Figure 8–45. Impact of CFLs on Reliability

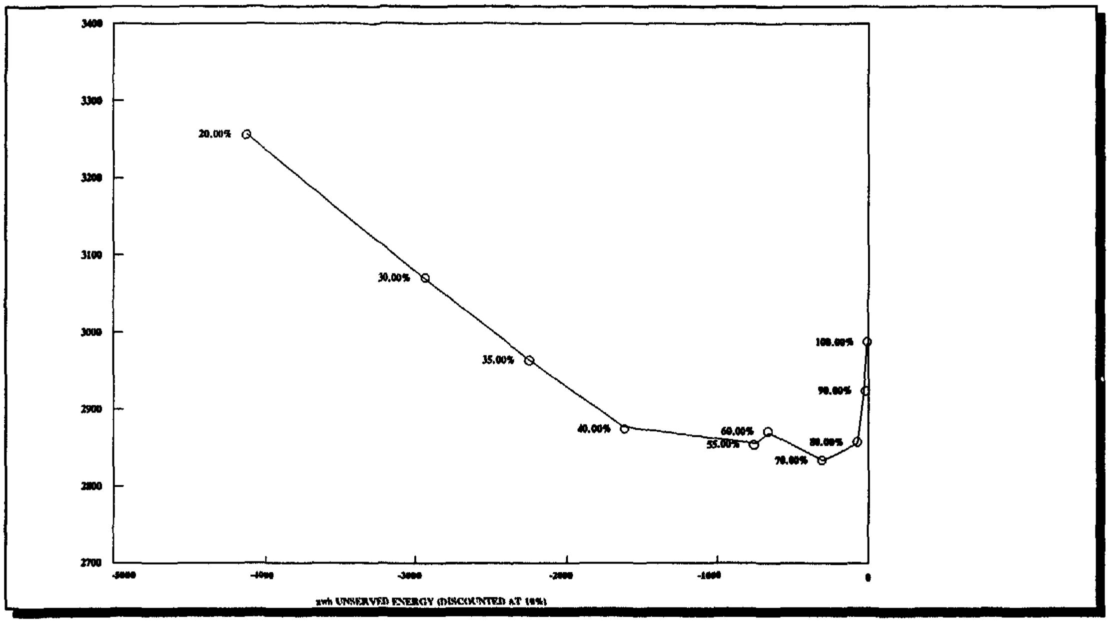


Figure 8–46. Unserved Energy as a Separate Attribute

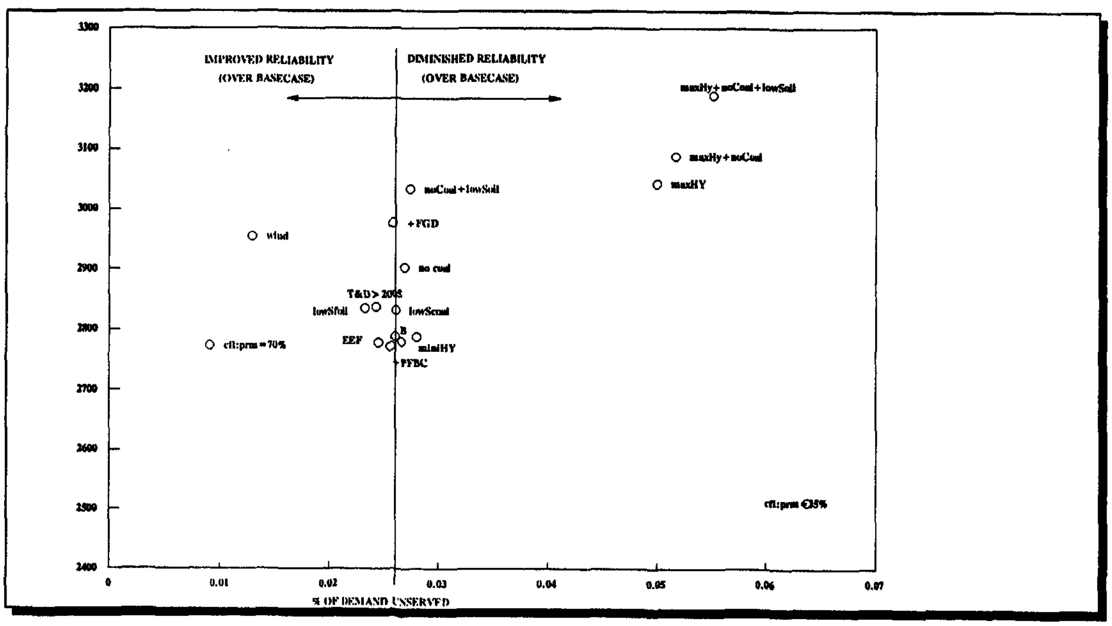
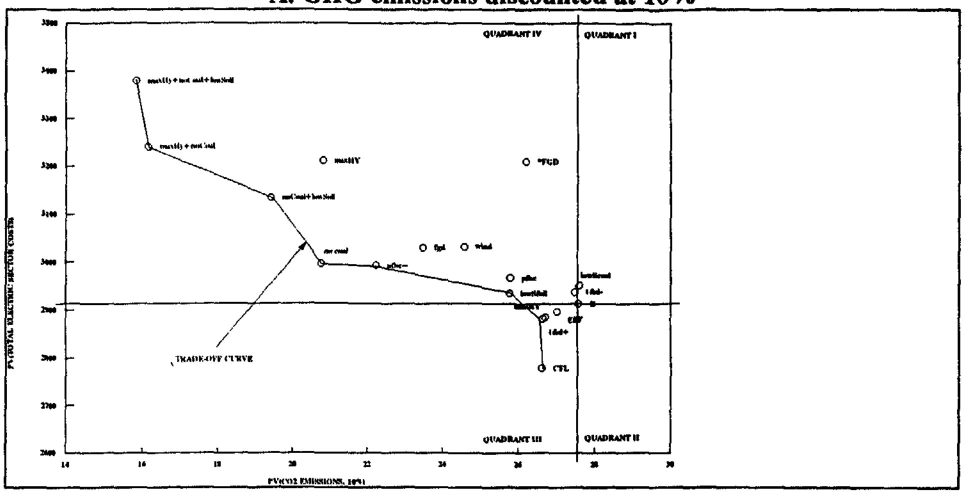
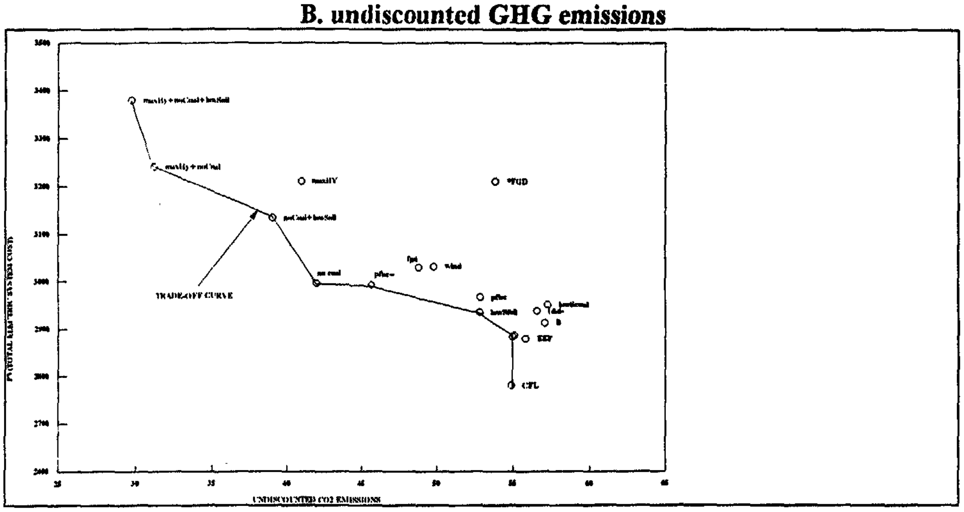


Figure 8–47. Trade-off Curves for Different Discounting Assumptions for GHG Emissions

A. GHG emissions discounted at 10%



B. undiscounted GHG emissions



C. Year 2011 GHG emissions

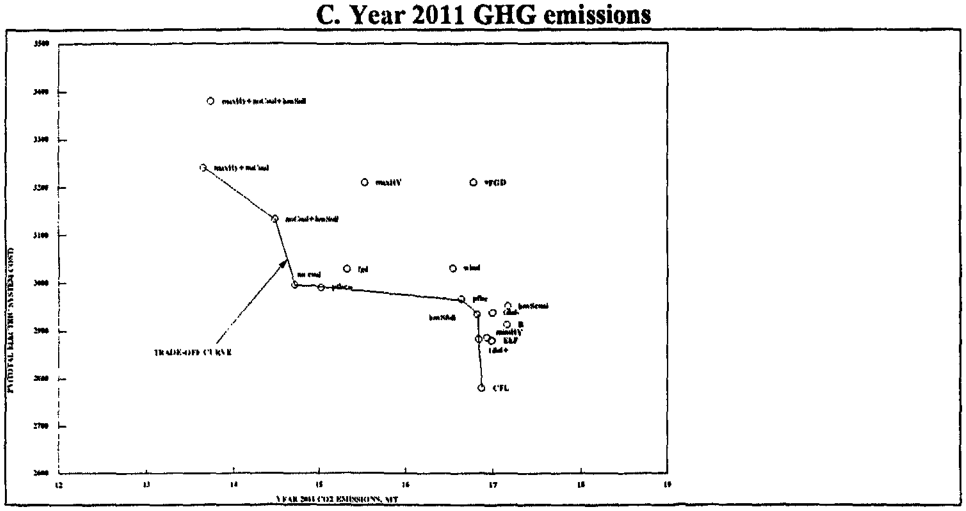


Figure 8–48. Generation Mix in the CEB's Expansion Plans Capacity

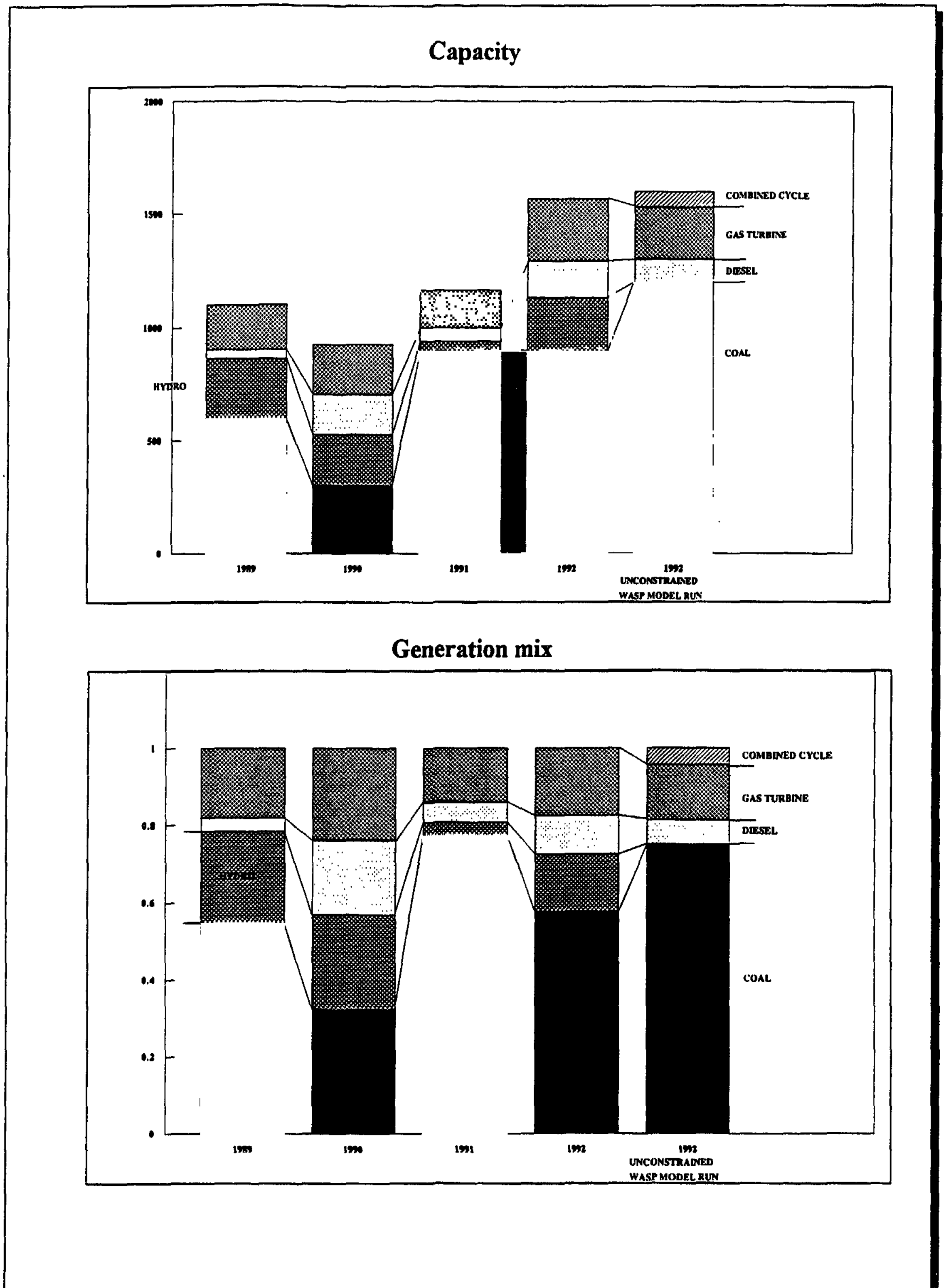


Figure 8–49. CEB Demand Forecasts

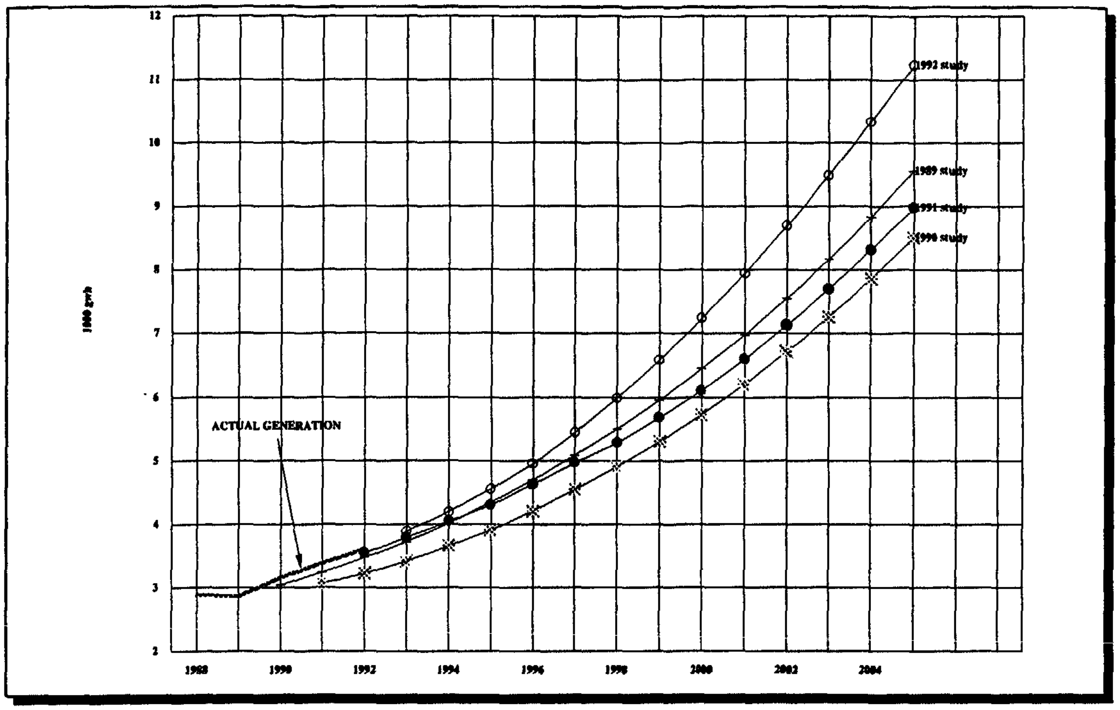


Figure 8–50. Changes in Hydro Projects from 1991 to 1992

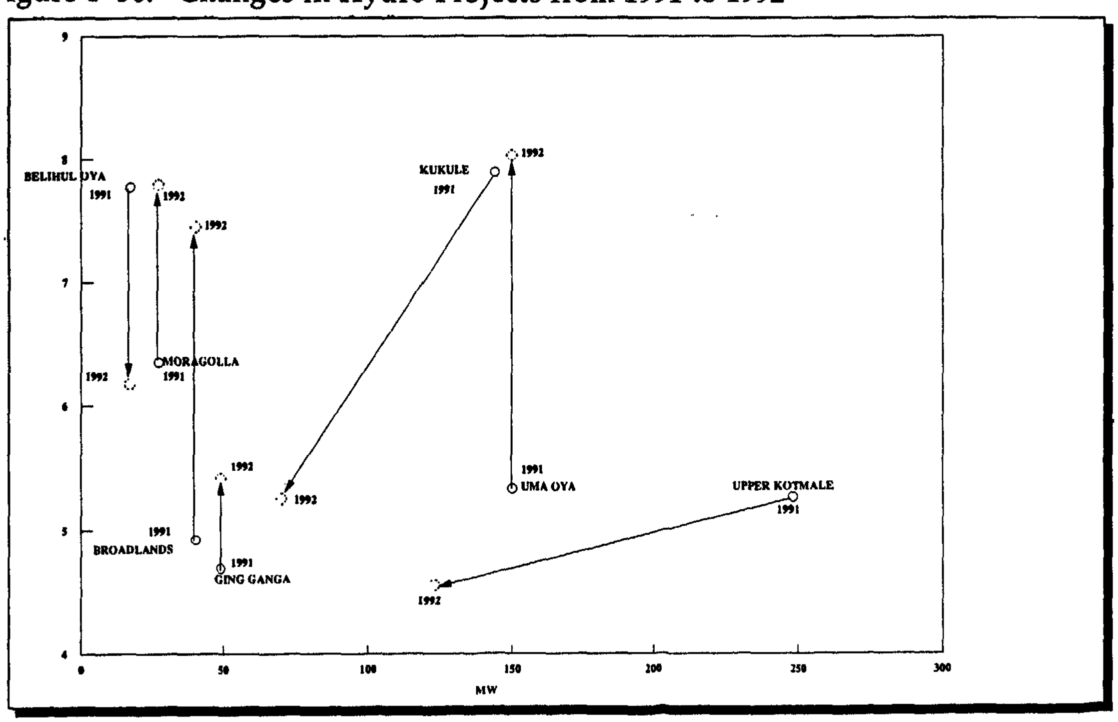


Figure 8–51. World Oil Price Scenarios

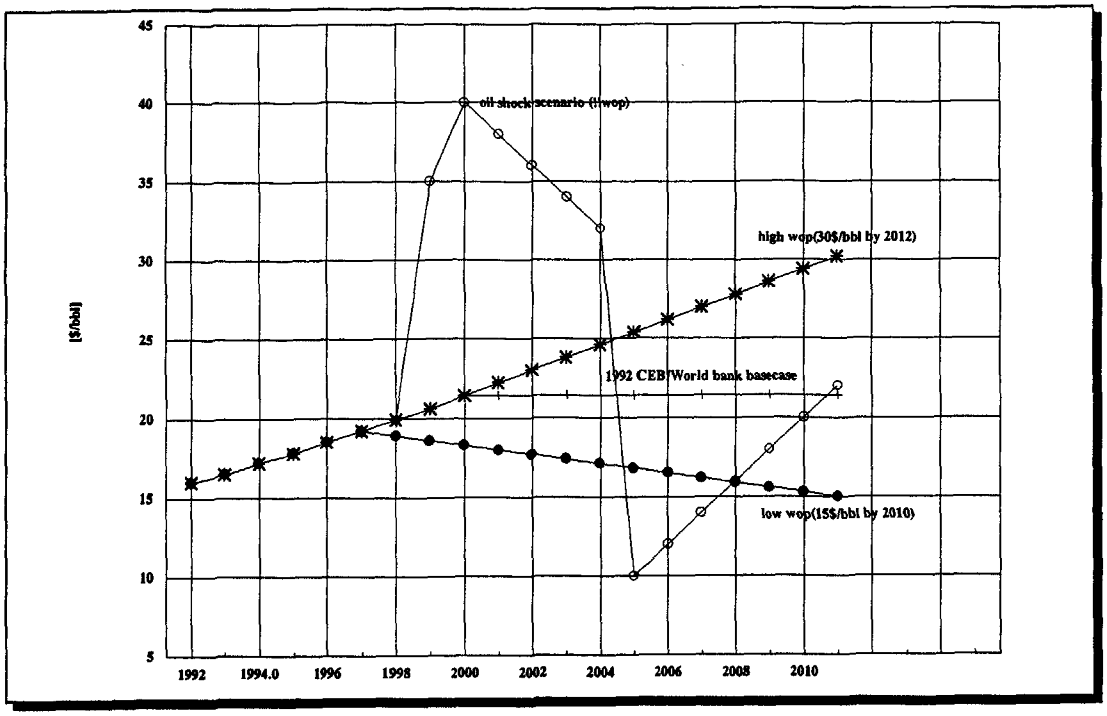


Figure 8–52. Import Duty as a Proportion of Total Revenue Requirements

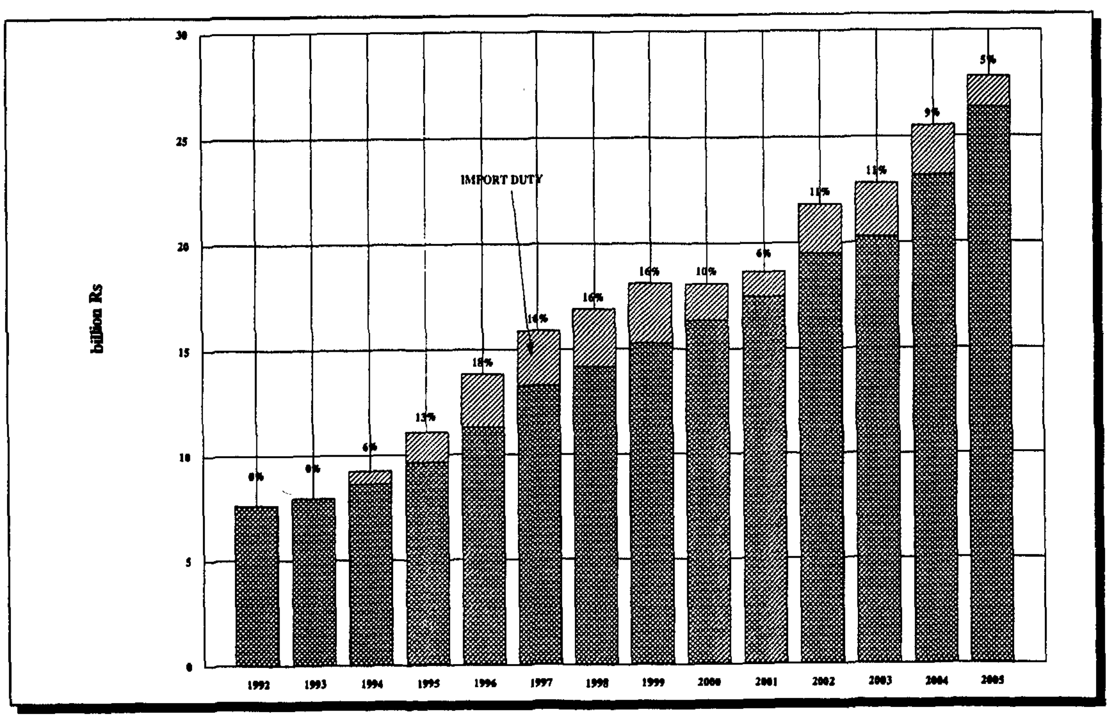


Figure 8–53. Definition of Futures

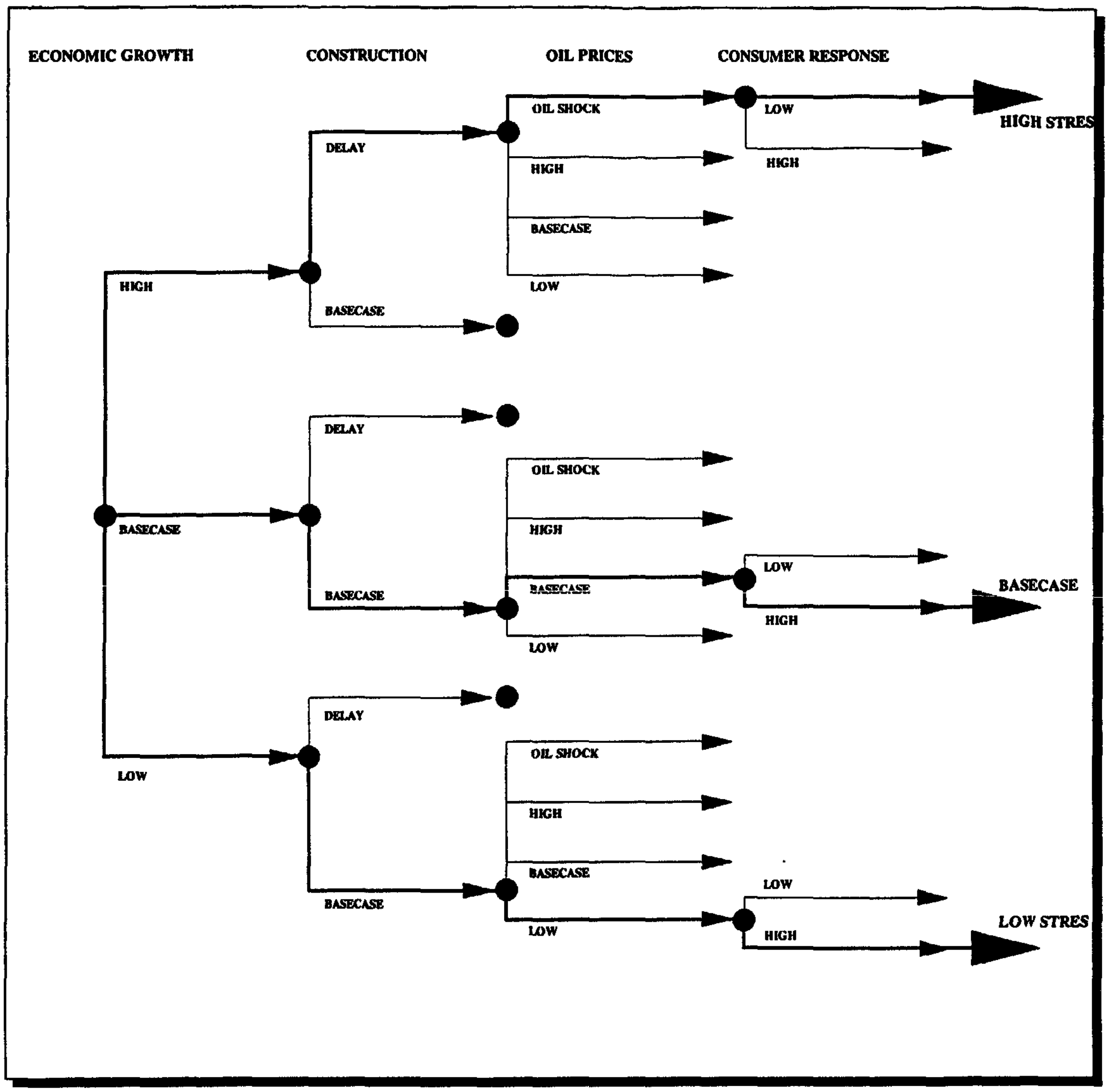


Figure 8–54. GHG Emission Impacts (pricing)

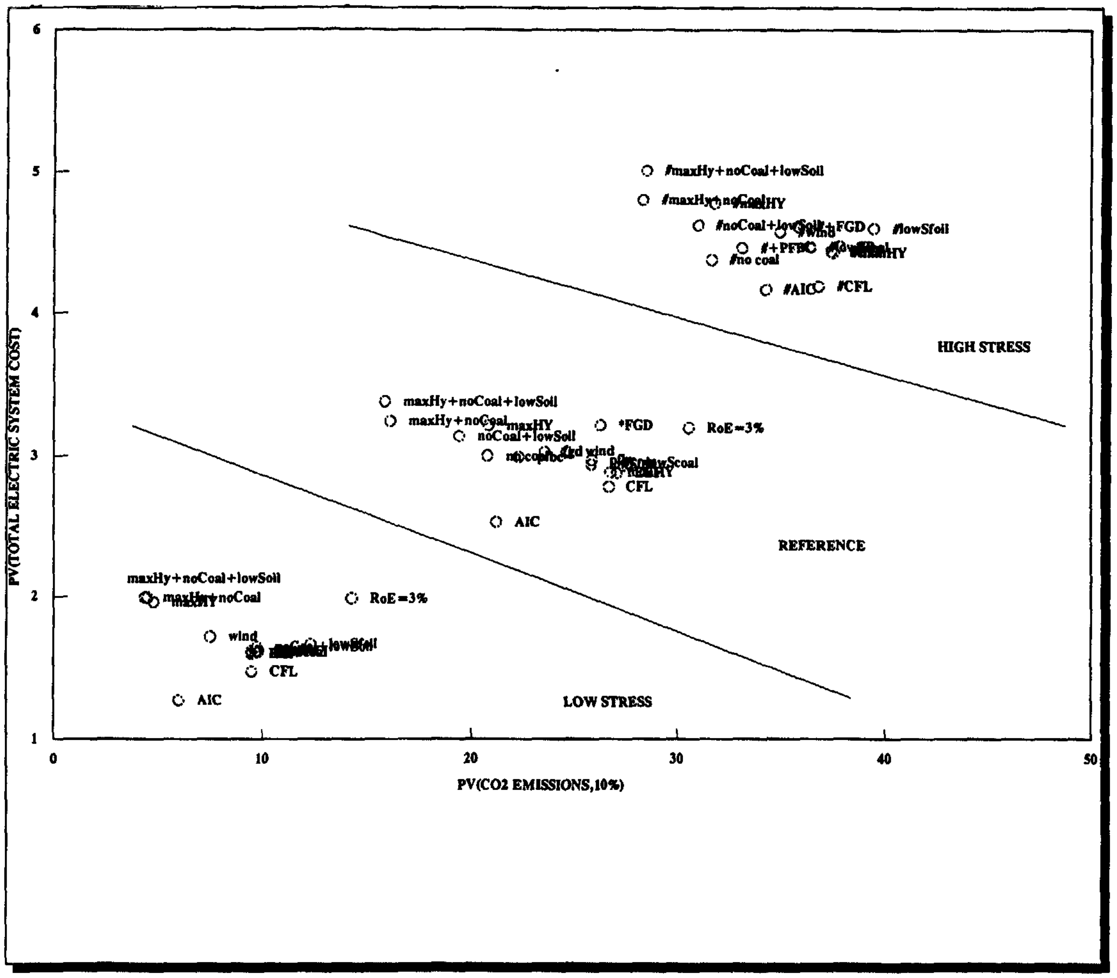


Figure 8–55. GHG Emission Impacts (health)

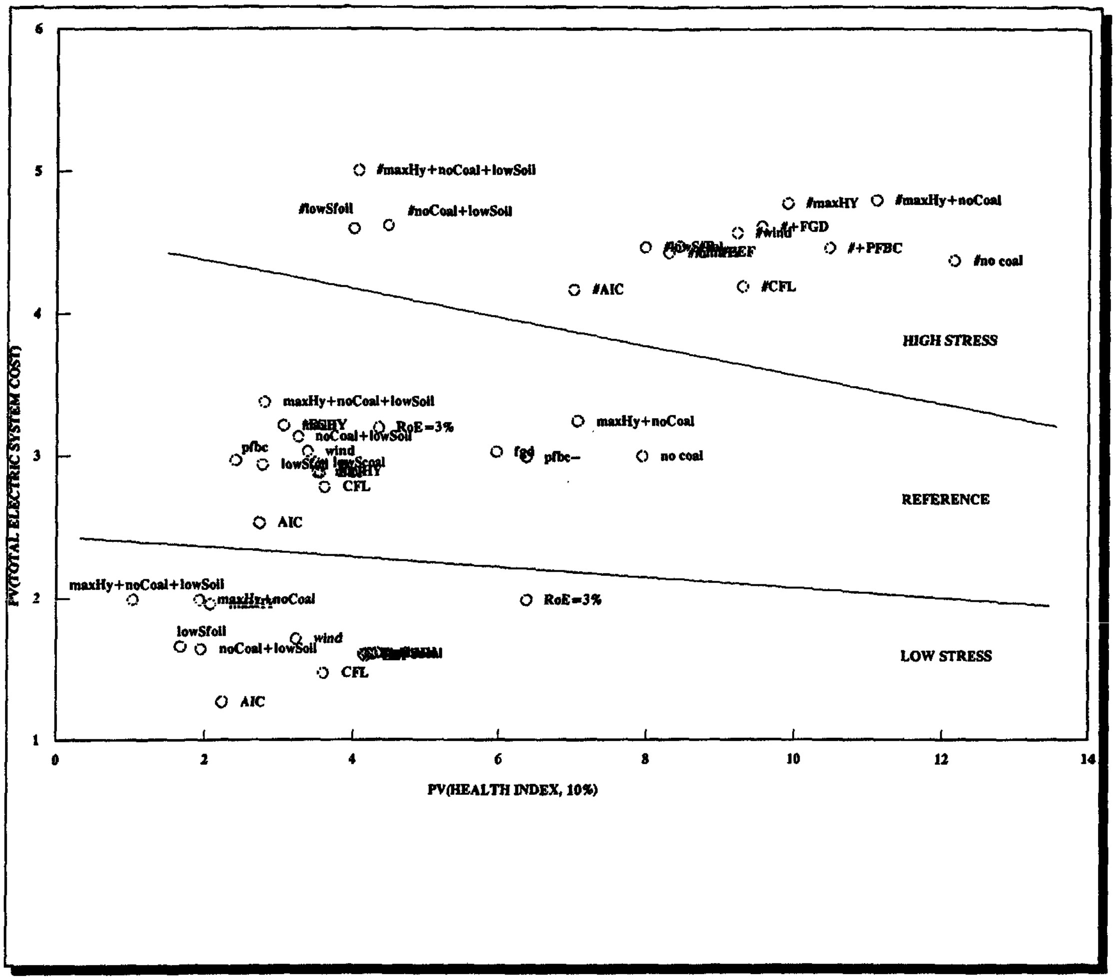
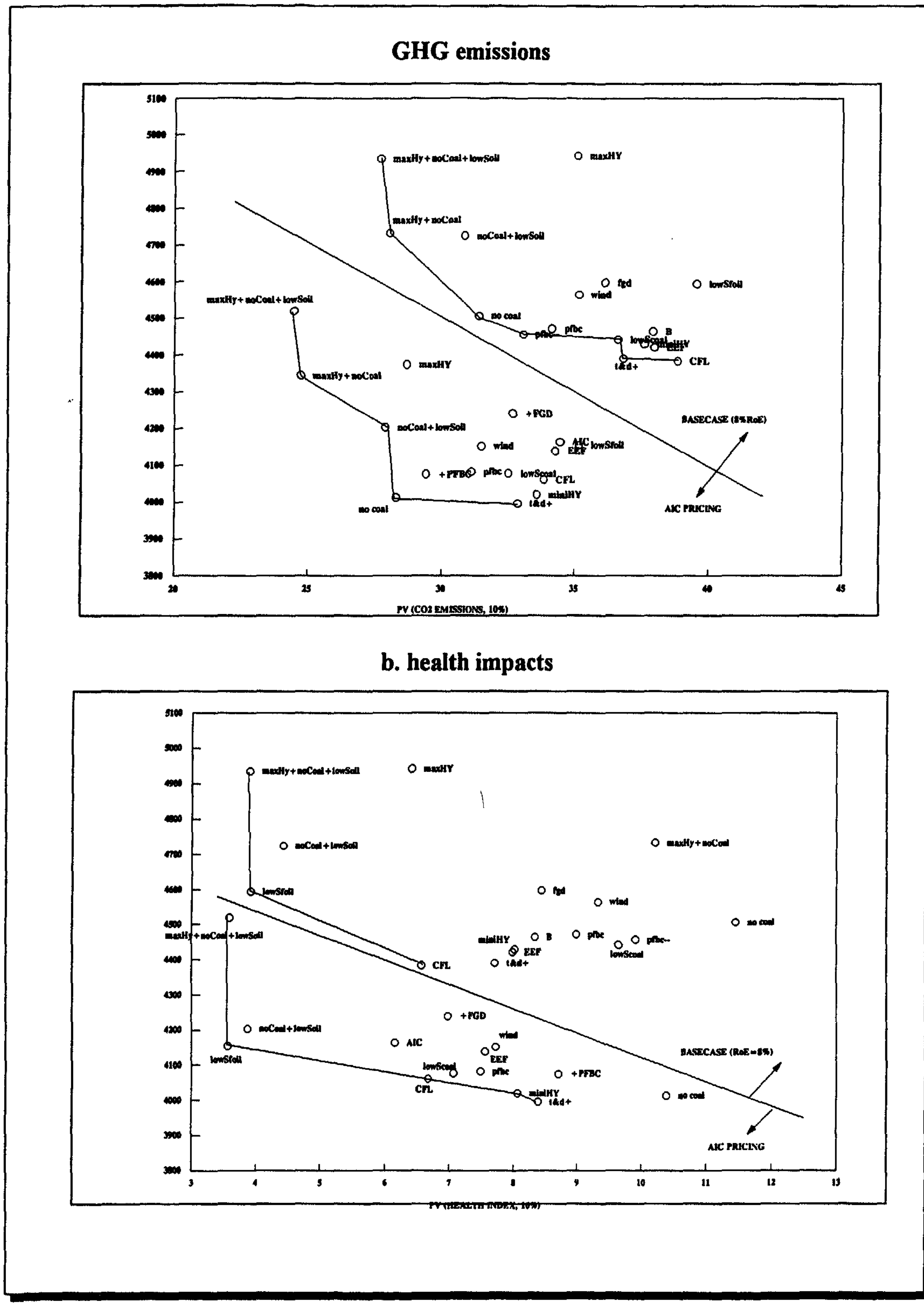


Figure 8–56. Comparison of Pricing Strategies in the High Stress Future



Notes

1. The writers acknowledge the many contributions from our colleagues in Sri Lanka, especially D. C. Wijeratne and K. Nanthakumar.
2. A recent review of such lending found that electricity tariff reform was an extremely common component of adjustment policy packages: Warford, Cruz, and Hansen 1992. Between fiscal 1988 and fiscal 1992, tariff reforms were part of structural adjustment lending in Bangladesh, Laos, Papua New Guinea, Guyana, Honduras, Panama, Venezuela, Bulgaria, Czechoslovakia, Egypt, Hungary; Poland; Romania, Benin, Burundi, Côte d'Ivoire, Rwanda, Senegal, and Zimbabwe.
3. In the case of Global 2100, a variant of the earlier ETA-MACRO model, the system has three sectors: goods, electric energy, and delivered non-electric energy. The production function for goods is a hierarchical system with a constant elasticity combination of Cobb-Douglas value added and energy inputs. (See also Hogan, *op.cit.*, for a succinct review.)
4. In fairness one might note, however, that to describe such impacts as small depends upon one's perspective. K. Yamagi and others. (1993), describe the effect of the level of their estimate of a carbon dioxide tax necessary to stabilize emissions at the 1988 level as "prohibitive expensive", their estimate is a cumulative GNP loss of 3 percent between 1990-05 (or an effect on the annual GNP growth rate of -0.3 percent). This is true even if the carbon dioxide taxes are returned to the economy through an income tax offset.
5. For several reasons, the Burgess estimates of the impact of LRMC pricing may be on the high side. First, the reductions are assumed proportionate to the generation mix. For example, in India, the assumed figure is 66.2 percent coal, 7.8 percent oil, and 1.1 percent gas (the remainder being hydro and nuclear). Yet when the likely merit order is considered, a much higher proportion of the saved electricity will accrue at higher cost oil-burning plants, for which the carbon dioxide savings will be less. Second, the assumed price elasticity of -1 is considerably higher than what can actually be seen in econometric studies (in the case of Sri Lanka, as we shall see in Annex 2, price elasticities are in the range of -0.15 to -0.4, depending on assumptions, but certainly not as high as -1.)
6. See, for example, Center for Energy and Environment, University of Pennsylvania Costs and Greenhouse Gas Emissions of Energy Supply and Use. 1992.
7. For a detailed literature review of such efforts, see for example, Markandya. 1990.
8. The WASP model is a sophisticated dynamic programming model that optimizes the future expansion path of a power system subject to exogenously-specified demand projections and reliability requirements (such as loss of load probability).
9. Buhring and others 1991.
10. OKO Institute 1989.
11. See, for example, Crousillat 1989.
12. These methodological problems have been recognized by the GEF, which has initiated a research program to find an operational approach for measuring and agreeing upon full incremental costs within the context of the Climate Change Convention: the so-called PRINCE study (Program for Measuring Incremental Costs for the Environment).
13. Mathematically, the model consists of a set of simultaneous equations, solved by iterative substitution. Typically between twenty and thirty iterations are required for convergence.
14. Meier 1995.

15. However, the actual rate of T&D losses is generally regarded as being much higher than the reported figure, because the CEB includes in its overall sales figure the sales to the municipal authorities and Lanka Electricity Authority (LECO), a private, but still government-owned distribution company. Since the municipal authorities typically had loss rates of 30 percent or more, before being taken over and rehabilitated by LECO, the actual loss rate in 1992 is probably in excess of 20 percent.

16. Indeed, the CEB has recently decided to proceed with the run-of-river version of Kukule.

17. The rule of thumb concerning such matters is that the largest single unit ought not to account for more than 10 percent of the peak load, particularly in a system that is not inter-connected. While there have been discussions from time to time about linking Sri Lanka with Southern India by a transmission line across the Palk Straits—in the mid 1970s unsuccessful discussions were started on the possibility of Indian financing of the Kotmale hydro scheme, with payment in kind across such a transmission link—interconnection to South India does not seem very likely for some time to come.

18. For more detailed discussion of this controversy, see, for example, Meier and Munasinghe (1994). The fundamental problem with the EIS is that none of the alternatives considered involved anything else than once-through cooling into the shallow areas of the Bay. The incremental cost of shipping coal to a south coast site, that lacks a deeper harbor, far outweigh the cost of other potential remediation options, such as a long discharge into the deeper waters of the Bay (that is, below the thermocline). This would have had a beneficial impact as upwelling would have brought nutrients from the colder layers into the surface layers, thus benefiting fisheries. In short, the controversy resulted from lack of a properly defined benefit-cost analysis, not from any fundamental shortcomings of the site.

19. Indeed, there is now some discussion about Trincomalee being developed by a private investor group from Canada. This proposal, and its potential impact on CEB and on environmental indicators, is discussed further below.

20. Perera (1992) estimates the commercially available quantity at 258,000 tons, inadequate for a 100 megawatts power plant even for two years. Moreover, this peat has a high sulfur content, about 5 percent, much higher than most commercial deposits in other countries (such as the 0.2 percent sulfur of Finnish peat).

21. Even if oil or gas finds were made tomorrow, experience elsewhere shows that the confirmation of commercially exploitable quantities, then offshore field development, and the development of the necessary delivery and distribution infrastructure (particularly for gas), takes ten to fifteen years. There are many examples (for example, Morocco, and the Meskala gas field, Senegal) where early optimism after initial discoveries proved unfounded. In short, even under the most optimistic circumstances, domestic oil and gas would unlikely be a power sector fuel until well past 2005. Moreover, converting a coal plant to gas and or oil, were it to be discovered, can be accomplished much more easily than converting an oil or gas plant to coal.

22. However, combined cycle units in tropical countries with high average ambient temperatures will have significantly lower efficiencies.

23. For the past four years, the Netherlands government has assisted the CEB in assessing the potential for wind generation in the South, and extensive wind measurements have been taken. The prospects for wind generation in Sri Lanka

are at least as favorable as in India, where a number of large scale wind farms are planned for the east coast. For example, the government of Andhra Pradesh has just approved the selection of seven private companies to develop 178 megawatts of wind power on a build-own-operate (BOO) basis. Tamil Nadu has similar plans to develop the wind potential of the coastal area.

24. Perera (1992) notes a number of other options that we have not addressed in the present study, but which merit further investigation. One is the completion of 25 megawatts of combustion turbine capacity at the Lanka Cement Company at Kankasanthurai, installed in the early 1980s but never fully commissioned. Other plants in Trincomalee and at the now closed State Fertilizer Manufacturing Corporation could also be used to provide stand-by power during drought conditions, and might avoid the need for new small thermal capacity which will otherwise be needed to meet reliability requirements during the 1990s.

25. A recent review of the costs of alternative electricity generation costs suggests current costs of solar thermal plants of 15 U.S. cents per kilowatt hour, compared to 5 U.S. cents per kilowatt hour for coal, and 4.5 U.S. cents per kilowatt hour for gas-fired combined cycle. The prospective long term costs are for solar thermal to decrease to about 7 U.S. cents per kilowatt hour , while coal and natural gas plants may rise somewhat with fuel cost increases. For details, see Anderson and Williams (1993).

26. Ceylon Electricity Board. 1992. "Wind Energy Resources Assessment: Southern Lowlands of Sri Lanka, Interim Report." May. Capital costs for a 10 megawatts pilot plant were estimated at a total of US$1,300 per kilowatt. The annual average load factor is 71 gwh for 50 megawatts.

27. There seems to be little correlation between rainfall and wind speed. The standard deviation of annual output at a nominal 50 megawatts plant in Bundala was estimated at only 12 percent: in the severe drought year of 1983, output at the wind plant was above average.

28. GTZ Masterplan, Volume A-2: Candidate Hydro Projects-Part II, September 1988. The projects are on the Mandgal Oya (4.63 megawatts), Maha Oya (9 megawatts), and Kuru Oya (11.6 megawatts and 5.28 megawatts). All have specific costs of less than 5 U.S. cents per kilowatt hour. However, there may be some uncertainty attached to these cost estimates, given the preliminary nature of the investigations performed by the masterplan study for mini-hydros: the likelihood is that these estimates may increase substantially. For example, the cost estimates for the 40 megawatts Broadlands hydro project, which appeared for many years in CEB's least-cost plan, have recently been found to be substantially understated, and the project no longer appears in CEB's least-cost capacity expansion plan.

29. Such assessments have recently been conducted for India as part of a recent World Bank/USAID power sector review. For Costa Rica, see USAID (1991).

30. The World Bank study also examined the possibility of replacing self-ballasting mercury vapor and incandescent lamps used for street lighting by high pressure sodium vapor bulbs.

31. For a review of the European experience, see, for example, Mills (1991) The average cost of conserved energy of these programs is reported at about 2.1 U.S. cents per kilowatt hour, including 0.3 U.S. cents per kilowatt hour for indirect administrative, promotional, and evaluation costs. This is significantly below the cost of new electric power plants. An analysis for Pakistan (Miller, Geller, and deAlmeida. 1992) concludes that even if the government offered a 100 percent subsidy—that is, literally gives them

away—it would save US$10 per bulb in avoided power plant construction costs.

32. Improving the energy efficiency of refrigerators appears as a top-ranked option in many assessments of demand side management measures in developing countries. For example, this measure emerging as the best among twenty-three options, and improvements to compressors and insulation of Thai refrigerators, is estimated to reduce unit electrical use from 400 kilowatt hours to below 200 kilowatt hours per year (see Florida Solar Energy Center 1991). Indeed, an analysis of efficiency improvements in major residential appliances in the United States (Schipper and Hawk 1991) indicates that refrigerators and freezers have shown the best improvements in efficiency since 1972, improving 70 to 90 percent, whereas efficiency improvements of other major devices have been much more modest (air conditioners 33 percent, space heaters 10 to 25 percent).

33. In commercial buildings, where the lighting load is often more evenly spaced during the day, there may be a further multiplier effect (although ignored in this study) namely a reduction in air conditioning loads. Since incandescent bulbs convert a much higher fraction of the energy input into heat than do fluorescents, in tropical climates one would therefore expect air conditioning loads to fall as a side-effect of the use of high efficiency lighting. A recent study in Thailand (Busch, DuPont, and Chirarattananon 1993) suggests that of the total savings associated with the introduction of high-efficiency lighting in the commercial sector, between 13 to 23 percent are savings in air conditioning, and 2 to 15 percent in ventilation loads.

34. It must however be stressed that there is no empirical data whatsoever on the composition of the hour-by-hour loads by end-use device in Sri Lanka. However, peak air conditioning loads almost certainly occur during the daylight hours, since the bulk of air conditioning is installed in offices and hotels rather than private residences. Consequently the assumption that a significant share of the evening peak is attributable to residential lighting seems reasonable.

35. There are four 70 to 80 megawatts scale units currently in operation in the United States, Sweden, and Spain, with units in Japan and Czechoslovakia shortly to become operational. Full scale, 350 megawatts units are anticipated in the United States and Japan by the end of the decade. For a discussion of recent PFBC unit performance, see for example Smock (1993).

36. The sensitivity of results to capital costs is discussed further along; see also table 8–8.

37. In fact, actual loss rates are likely to be somewhat higher, since CEB treats HT sales to the Lanka Electricity Company (LECO), a privatized, although still government owned, distribution company established in 1984, as a consumer. Since LECO has losses of its own (some of the municipal systems that were absorbed by LECO had loss rates exceeding 30 percent prior to rehabilitation), total losses in the system are at least 2 to 3 percent higher than CEB's estimate based on its generation and sales.

38. In our earlier work we examined the relative contribution of greenhouse gas emissions from hydro and coal plants. Indeed the contribution to greenhouse gas emissions that result from any removal of forest from reservoir areas and inundation of vegetation are very small in comparison to the GHG emissions from an equivalent fossil fuel plant.

39. Including the high dam version of the Kukule project (at 144 megawatts, rather than the 70 megawatts variant that is currently under consideration), both plants in the Upper Kotmale scheme (rather than just the lower run-of river project at Talawakelle), and the Uma Oya multipurpose scheme.

40. The perception of traffic congestion is of course somewhat subjective, since perceptions have much to do with rates of change. Certainly by the standards of Bangkok or Bangalore, traffic conditions in Colombo are still relatively good.

41. The refinery data for 1992 shows that out of total petroleum product consumption of 1.2 million tons, 569,000 is auto-diesel, and 159,000 is gasoline (that is, road fuel accounts for 60 percent of the total). Electricity generation accounts for 80,000 tons, other fuel oil and heavy diesel 192,000, kerosene 177,000, and LPG 42,000 tons. Until recently, no fossil fuel was needed for electricity generation in an average hydrological year.

42. Coal consumption in Sri Lanka is negligible. In 1990 about 2,000 tons were imported, used by the railways. (Ceylon Electricity Board 1990.)

43. This has been noted by many observers, including Meyers (1988), who notes: "...the number of vehicles in use is not well-defined for most developing countries. Careful examination of statistics suggest overestimation of the actual vehicle park...compounding the problem is the fact that vehicle categories used in registration accounting may change over time, or exhibit suspiciously large or small changes from year to year"(p.16). A good example of the latter problem is the Sri Lanka statistic for "dual-purpose vehicles," which was introduced as a category in 1985. Such vehicles were previously included under "Lorries: vans and tractors." As a result, new registration in the latter category fell dramatically, from 2,164 petrol vehicles in 1984, to thirteen in 1986, while "dual purpose vehicles" increased from zero in 1984 to 2,673 in 1985).

44. Indeed, when we subtract from the total gasoline and auto-diesel the amounts of auto-fuel used by the fishing fleet, the army, and land vehicles (categories often missing from transport sector fuel consumption and environmental impact studies, all known to be non-zero), the paradox is even more striking.

45. This estimate of passenger kilometers traveled makes several heroic assumptions: (1) that there is one passenger per kilometer traveled on motorcycles which, given the fact that sometimes as many as two adults plus two children are observed on a single motorcycle, is probably an underestimate, and (2) that the average occupancy in automobiles is one and a half passengers per vehicle kilometer driven. Vehicle kilometer traveled is based on our model, documented below. Whatever such assumptions, however, the conclusion remains unchanged.

46. There are, to be sure, some important differences, such as, for example, the large number of LPG-fueled vehicles in Thailand. But the main reasons for the decline are much the same: a huge growth in the motorcycle population for gasoline vehicles, and the growth in small diesel commercial vehicles (pick-ups, vans, and so on). In fact, in 1986, the ratio of motorcycles to cars was 2,102,000 to 738,000 (or 2.84:1) in Thailand, compared to 1.88:1 in Sri Lanka in the same year; but by 1990, the ratio in Sri Lanka had risen to 2.97:1.

47. The econometric analysis presented in this section indicates high own-price elasticity for gasoline, but little if any price effect for diesel consumption.

48. For an extensive review of transportation energy models, albeit for the United States, see for example Beaton, Weyland, and Neuman (1982).

49. For a thorough review of the recent literature, and a useful classification of model structure, see Dahl and Sterner (1991).

50. This mirrors the experience of econometric studies of electricity demand, where exclusion of the number of con-

nections frequently results in over-estimation of the income elasticities, and the absence of any significant price effect. A proper model specification for electricity demand first examines the number of connections (which are often much more a function of rural electrification policy, and financial constraints on expansion of the distribution in urbanizing area than on price and income variables). Then in a second stage, one models the demand per connection. (See Annex 3 for further discussion.) Thus, it comes as no surprise that in the transportation sector as well, we need to separate the number of vehicles, and the consumption per vehicle, as explanatory variables. Indeed, the parallel with electricity goes even further, for just as electricity consumption per connection has fallen dramatically over the past twenty years in Sri Lanka, so has gasoline consumption per vehicle!

51. That is, about 90,000 vehicles for a population of 17 million. By contrast, in 1986, Thailand had about 738,948 passenger cars for a population of 52 million, that is, 0.0142 cars per capita. Indeed, the claimed saturation level of 0.25 vehicles per capita as an appropriate saturation rate for developing countries seems quite extraordinary. The KEEI study, which also used a logistic specification, used 0.12 as the saturation value for cars (KEEI, *op.cit.* p.129).

52. However, a real price index for passenger cars for use in a similar model for Korea leads to the perverse result that the estimated coefficient—which was statistically significant—has a positive sign (the higher the price, the higher the car ownership).

53. Nor was a weighted aggregate price index of auto fuel, in which diesel and gasoline prices were weighted by vehicle numbers of each type, or by consumption of each fuel.

54. GDP elasticities for car ownership in the low-income countries group reported by Button and others. (1993) lie in the range 0.699 to 0.73.

55. Needless to say, it is not sufficient to set the tariff itself to an economically efficient level: this must be accompanied by appropriate policies for metering, billing, and collection.

56. Ceylon Electricity Board 1993.

57. In fact a fuel adjustment clause was introduced into the tariff in 1978, but was not implemented until October 1980 due to difficulties in calculation and assessment. For a discussion of electricity pricing in the 1970s see World Bank (1982). "Sri Lanka, Issues and Options in the Energy Sector." Report 3794-CE. Washington, D.C.

58. See for example Ceylon Electricity Board 1992.

59. However, the shares are still held by the government.

60. In 1990, the overall loss rate in the LECO service area was 14 percent. Mahara, taken over in June 1985, with a loss rate of 48 percent, was brought down to 13 percent by 1989; Welisara, taken over in December 1987 with a loss rate of 41 percent, had lossesof 11 percent by 1989; and Kolonnawa, taken over in November 1985 with a 50 percent loss rate, was down to 21 percent by 1989. This substantial improvement in performance was attained by a combination of system rehabilitation (mostly with ADB assistance), in which the distribution system in some areas were almost completely rebuilt; and an aggressive policy of disconnection for non-payment of bills.

61. That is, generation of 2.21 rupees per kilowatt hours + T&D = 3.68 rupees per kilowatt hour = 5.29 rupees per kilowatt hour overall.

62. The exact definition used by CEB is the present value of total system costs (capital and operating costs of new facilities

plus operating costs of existing facilities) over the next fifteen years divided by the present value of generation requirements over the same period less the present value of generation from existing hydro. This is a good approximation of the AIC since in the average hydro year, the current energy demand is almost exactly met by the existing hydro plants.

63. Ideally, the LRMC at the consumer level would also be endogenously calculated by the model. This becomes important primarily for the assessment of the cost-effectiveness of T&D system rehabilitation. Obviously, if the target level of losses moves from 12 to 10 percent, the incremental LRMC for T&D would also decline. For the moment this effect is not considered in our model.

64. Health impacts from fossil fuel combustion is expressed by an index that captures the population exposure to the incremental increase in ambient concentration of fine particulates and NO_x. A simple gaussian plume model was applied to all major power plant sites to estimate the unit impact under average weather conditions. For further details, see Meier and Munasinghe 1992.

65. Impact on biodiversity is measured by an index number that represents a relative measure of the biodiversity value of the habitat lost. One hectare of lowland wet evergreen forest was assigned a value of one; a comparable hectare of monocultures (rice paddies, tea plantations) was assigned a value of 0.001, with other habitats assigned intermediate values. While such scales do involve subjective judgment, the scale was developed by the eminent ecologist K. Arudpragasam, Professor of Ecology at the University of Colombo and former Chairman of the Central Environment Authority of Sri Lanka. For further details, see Meier and Munasinghe 1992.

66. Our base case uses, as does the 1992 generation planning study of the CEB, the 1992 World Bank world crude oil price projection, which calls for a gradual increase (in 1992 U.S. dollars) from US$16 per bbl in 1992 to US$21.4 per bbl (fob Singapore) by 2000, and constant thereafter. In our low case ("-wop"), we assume that after an initial increase, the price falls, to US$15.30 per bbl by 2010. In our "oil shock" scenario (shown in figure 8–23 as "!!!wop"), the real price of crude oil rises sharply to US$38 per bbl in 1999, and US$40 per bbl in 2000; then parallels the trajectory of the 1980s with a slow drift downwards, a sudden collapse in 1985 (2005), followed by a gradual increase back to US$20 per bbl by 2010. Clearly history is not likely to repeat itself exactly, but such an oil shock scenario is probably a lot more likely than gradual changes.

67. In the litigation delay scenario we assume that fours years into construction commencement there is a two year delay, applicable only to large hydro and coal plants. The rationale is that such plants are the ones most likely to incur delays: smaller run-of-river plants are assumed less likely to incur delays, not just because engineering geological uncertainties tend to be less, but primarily because they largely avoid the problems associated with resettlement of inundated villages. For example, the run-of-river variant of the 70 megawatts Kukule hydro project requires resettlement of about twenty-seven families, while the 270 megawatts Upper Kotmale scheme requires resettlement of about 1,900 families. (Japan International Cooperation Agency. August 1987. "Feasibility Study on Upper Kotmale Hydro-electric Power Development Project.")

68. For a discussion of the justification for the use of a lagged dependent variable in electricity demand work in developing countries, see for example Westley (1985).

69. The value of -1 as used by Burgess (1990). in her study of the impact of LRMC pricing

on GHG emissions is probably on the high side in the case of Sri Lanka's. The studies by Westley for a range of Latin American countries also show long-run price elasticities of demand for electricity that are in the -0.5 to -0.8 range.

70. Such taxes obviously have substantial implications for the energy mix. For the world carbon tax scenario, coal falls from about 50 percent of global year 2100 energy consumption to less than 5 percent; total energy consumption falls by about 45 percent, and nuclear takes an almost 50 percent share.

71. This assumes that over the next fifteen years, OECD countries embark upon a massive nuclear power expansion program—an assumption that seems reasonable only in the case of France, which presently produces 70 percent of its electricity from nuclear power. Apart from this assumption, the tax level would need to double to about US$200 per ton.

72. An earthquake on the east coast of Luzon in July 1990, for example, caused a 2.5 meter fall in large areas of the coast, requiring large scale evacuation of coastal villages.

73. The classic example is Shanghai, which subsided about 2.5 meters between 1920 and 1965. An artificial recharge program was, however, successful in arresting further subsidence. Parts of Bangkok are now subsiding several centimeters per year, and many other coastal cities in Southeast Asia face potentially serious subsidence problems.

74. That can, at least in part, be attributed to large scale mining of coral reefs.

75. For a good review of the likely impacts of global warming in the South Asian countries, see for example Pachauri (1991). It would seem that the impacts of sea level rise, however serious for Sri Lanka, will not have the cataclysmic consequences that seem likely for the Maldives and the East Coast of Bangladesh.

76. We note also that the tradeoff analysis and surfaces will be much more complex as the number of attributes increases.

77. Decision analysis distinguishes among several types of dominance, such as strict dominance and significant dominance. See Meier and Munasinghe (1994), for a detailed discussion. The option A is said to strictly dominate the option B if A is better than or equal to B in every attribute, and strictly better in at least one.

78. See below for a discussion of the difference between the two FGD cases.

79. This of course is a widely debated subject. However, what may be calculated as monetary benefits need not necessarily be regarded as benefits to decision-makers, since there may be other, non-monetary costs involved. In our context of multi-criteria analysis, it means that when that third attribute is added to the two dimensional plot, in three dimensions such options are no longer in the multi-dimensional equivalent of quadrant 3. In the case of developing countries, the unavailability of finance may constrain the ability to implement such options. For example, until very recently, obtaining finance through export credits for power generation expansion schemes has been much easier than financing energy efficiency measures.

80. In general, of course, the tradeoff curve may extend into quadrant II; and quadrant III may contain fewer, or need not contain any solutions at all.

81. Moreover, there is the additional effect that at least for limestone scrubbers, carbon dioxide is released by the chemical reaction $CaCO_3 + SO_2 + 0.5\ O_2 \Rightarrow CaSO_4 + CO_2$, although the heat rate effect is very much more important.

82. It should be noted, however, that this is not always the result, since what determines the outcome is the ratio of coal to heavy fuel oil price. In the case of high oil to coal price ratios, coal plants with FGD

systems may in fact be preferred to diesels. However, the result that FGD is always inferior to PFBC is robust under wide ranges of fuel price (and other) uncertainties.

83. This result is readily demonstrated: 1 percent by weight sulfur coal, with 6660KCal/Kg, at facility with a heat rate of 2,600 KCal per kilowatt hours emits $0.01 \times 2600 \times 1.988 / 6600 = 0.0078$ Kg SO_2 per kilowatt hours. Two point five percent by weight sulfur oil, with 9822Kcal/kg, at a facility with a heat rate of 2376 Kcal per kilowatt hours, emits $0.025 \times 2376 \times 1.988 / 9822 = 0.012$ Kg SO_2 per kilowatt hours.
84. However, Sri Lanka's refinery is also located at Sapugaskanda, and in normal hydro years it is a much larger source of air pollutants than the diesels. Moreover, both of these facilities are smaller sources of particulates, NOx and SO_2 than urban transportation, whose emissions are at street level in the most densely populated areas!
85. The comparison seems valid, insofar as our base case relies largely on large coal plants.
86. This is analogous to the modality of payment of business turnover tax by the CEB, which is built into the tariff at the 5 percent rate, and paid by the CEB.
87. Defined as the PV of electric system costs plus the value of taxes raised.
88. The estimates of total government revenue are based on the projections in the 1992-96 Public Investment Plan (October 1992. Department of National Planning, Ministry of Policy Planning and Implementation. Colombo), and then extrapolated using the same GDP growth as assumed for the demand projections. In 1991 total government revenue was 74.5 billion, representing about 20.1 percent of GDP. Of these receipts, the BTT accounted for 21.4 billion, import duty 18.6 billion, income tax 9.7 billion.
89. Obviously, the most important simplifying assumption in this analysis is that price discrimination and the miscellany of different tariffs makes a calculation of the actual consumer surplus very much more complicated than indicated here.
90. In such algorithms, capacity additions are triggered whenever the reserve margin would otherwise fall below the specified value.
91. This finding that wind power will improve the reliability of the system is consistent with the detailed simulation studies of wind energy conducted by EB with the WASP model (CE. 1992), in which it was found that 88 percent of the energy from a hypothetical wind plant in Southern Sri Lanka displaces thermal power, and 12 percent reduces the expected deficits in generation.
92. In the reference case where we assume a perhaps somewhat optimistic effectiveness, CFL dramatically reduces the peak demand. Therefore, the 35 percent PRM criterion has the result of building significantly less capacity than in the base case, so that in dry years there is much more unserved energy. In order to achieve comparable reliability to the base case, it is logical that the optimal PRM would increase.
93. The original Japan International Cooperation Agency (JICA) feasibility study argued for a two-reservoir project: an upper reservoir with significant storage capacity, also known as the Caledonia project, and a lower run-of-river project at Talawakelle. The change in the 1992 study was a result of the assumption that only the lower run-of-river project would be built (not only because it had better unit costs, but also because it avoids the large resettlement impacts of the upper reservoir).
94. The Bank's record in forecasting oil prices, for example, has been quite poor, which is perhaps unfortunate because

developing countries make wide use of them for energy and power planning. Once again, the point is not to criticize those who prepare such forecasts, but to recognize that few forecasts are ever correct!

95. Expectations about the success of private power initiatives in Sri Lanka have undergone wide swings over the past year. In late 1992 there were very optimistic hopes about attracting private investment for a 2 x 150 megawatts coal-fired plant at Trincomalee. Needless to say, by mid-1993, more cautious sentiments about the practicalities of Trincomalee as a site for private power prevailed, and efforts have more recently focused on the more modest objective of making the 20 megawatts extension to the existing Sapugaskanda diesel station a private power project.

96. As originally proposed, this project would add 2,200 megawatts of gas-fired baseload capacity into the Maharashra State Electricity Board (MSEB) system. The gas is to be imported as LNG from the Middle East; and as a consequence the plant becomes the high-cost thermal unit in the MSEB system. The point is not to debate the merits of this proposed project—whose fate, ultimately, is much more likely to be decided by the ability of the institutional and regulatory mechanisms to deal with a project of such size than by economics alone—but rather to note that just two years ago, the proposition that a privately financed project of this size might even be seriously discussed in India would have been ridiculed, given India's ambivalent policies toward foreign investment in the power sector at the time.

97. The definition of terms is of course a matter of preference. However, the definitions used here are consistent with modern United States utility integrated resource planning practice.

98. In Sri Lanka, most run-of-river schemes involving minimal inundation have installed capacities of less than 100 megawatts; schemes larger than 100 megawatts typically require storage reservoirs that involve the relocation of several hundred families.

99. The 120 megawatts Samanalawewa hydro project will likely suffer at least a two to three year delay because of significant reservoir leaks that were discovered only once construction was complete and the reservoir was allowed to fill.

100. For example, the run-of-river variant of the 70 megawatts Kukule hydro project requires resettlement of about twenty-seven families, while the 270 megawatts Upper Kotmale scheme requires resettlement of about 1,900 families. (Japan International Cooperation Agency. August 1987. "Feasibility Study on Upper Kotmale Hydro-electric Power Development Project.")

101. Four fuel price cases x 3 macroeconomic futures x 2 capital cost scenarios x 3 construction delay cases x 3 elasticity/consumer behavior cases x 2 import duty cases = 432 possible futures.

102. Moreover, although we have not made any corrections for this, when demand growth is strong, distribution systems are even more likely to be overloaded, and hence experience higher loss rates. Phrased differently, the importance of T&D rehabilitation in urban areas is especially important during periods of high load growth.

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9

Agricultural Modernization and Resource Deterioration in Latin America

Jorge Torres

Fundamental aspects of the new economic strategies in the Latin American region are openness to international flows of goods, services, capital, and technology; economic liberalization; and deregulation of domestic markets. Governments of all countries are promoting economic growth by strengthening the private sector and the market system as well as by minimizing state interventions.

These new trends imply a new specialization of Latin American economies according to their natural comparative advantages. This in turn means a further specialization in those products that use intensively the region's most abundant resources. This chapter proposes that the region's most abundant resources are its natural resources—enormous land, water, and forest resources—as well as its great biological diversity.

Even if the prospects for rapid economic growth in Latin America in the years ahead seem unclear, the prospects for a rapid increase in exports are certain. An export boom is already taking place in some countries, such as Mexico and Chile, and this boom may turn out to be founded on the sale of commodities based on natural resources.

The thesis here is that this export boom will extend to most countries in the region by the end of the decade, generating a massive outflow to world markets of goods based on natural resources. The most important sectors contributing to the export drive will be agriculture, forestry, fisheries, and mining. The new export orientation implies modernization efforts in these sectors, and this modernization process will take new dimensions within the context of openness in an ever more interdependent world.

The projected export boom and modernization will have environmental impacts for two principal reasons. First, these processes imply a more intensive use of natural resources, of industrial inputs, and of existing capital stock than traditional activities (price effect). Second, they are also associated with a greater scale of production and new investment projects, which, in turn, have additional effects on the environment and on natural resources previously not used (income effect).

There is therefore a clear danger for resource deterioration and ecological damage. This danger is aggravated by the fragility of the region's tropical ecosystem, the high deforestation rates, and the high level of soil erosion affecting watershed basins. Furthermore, the increasing world demand for exotic commodities such as hardwoods and seafood may continue to be a force driving deforestation and resource degradation; these processes will be difficult to reverse unless the pattern of demand changes.

There is evidence that resource deterioration is already taking place, as shown by several case studies on agricultural modernization in Latin America, made by the Inter-American Institute for Cooperation on Agriculture (IICA). But we have seen only the tip of the iceberg. More ecological damage, at a higher pace and at new dimensions, may be expected from the massive effort to modernize export-oriented agriculture and to satisfy worldwide demand in the years to come.

The danger of overexploitation of natural resources explains why the issue of sustainability has become a focus of attention in the region. However, there is a clear contradiction of policies and objectives. On one side, incentives are being given to expand exports at any cost, while, on the other, a new natural resource conservation policy is being advanced. This simply restates the contradiction between short-run needs and long-run sustainability. Furthermore, this contradiction of policies is also implicit in the activities of the World Bank and the Inter-American Development Bank, which are currently financing conditional loans for countries fostering liberalization and exports. Although both banks express a concern for the environment, priority is clearly given to policies that "get the prices right," and the directive requiring projects to include environmental assessment seems to be at present no more than an intent to save face.

This chapter presents independent research to test the existence of a strong trend toward a massive export drive and resource deterioration. This study presents concrete evidence that resource deterioration is taking place in the most dynamic subsectors of the agricultural sector in Latin American countries. First, the most successful experiences of agricultural modernization are described, and then the environmental assessment of these export-oriented modernization processes is presented. Finally, alternative policies to ensure natural resource conservation, environmental enhancement, and a sustainable and competitive agriculture are discussed.

Agricultural modernization in Latin America

This section classifies and discusses the economic performance of selected subsectors of the agricultural economies of some Latin American countries in relation to policies, technology, and market dynamics. Some countries followed inward-oriented policies in the 1980s, others struggled with policy reforms, and others followed outward-oriented policies. The analysis includes the general correspondence between macroeconomic and sectoral policies and production patterns as well as the broad implications for natural resources.

A modernization process is one through which sustained increases in productivity and net income are attained at the enterprise level, without the existence of significant protection on behalf of the state. Because agricultural modernization is a main element of development strategy in Latin America, the IICA organized a series of studies examining the factors contributing to the modernization process. The eight case studies were grains in Argentina, soybeans in Brazil, flowers in Colombia, dairy products in Costa Rica, fruits in Chile, poultry in Peru, shrimps in Ecuador, and vegetables in Mexico.

The case studies first examined the process dynamics, through indicators such as production, productivity, net income by area or by enterprise, and number of participant enterprises. Then, they considered basic modernization factors: policies, markets, technology, and organization and management.

The fundamental conclusion of the analysis was that modernization should be interpreted primarily as modernization of the managerial enterprise and development of human capital. Further, the eight experiences were classified under four categories: (a) modernization of traditional commodity exports, such as grains in Argentina and soybeans in Brazil, (b) modernization of products with high income elasticity, such as Chilean fruits and Mexican vegetables, (c) development of new products of a sumptuary nature oriented to satisfy external demand, such as flowers in Colombia and shrimp in Ecuador, (d) modernization of products oriented to domestic markets, such as dairy products in Costa Rica and poultry in Peru.

This chapter summarizes these case studies according to the proposed classification. The study for Peru is not presented here because it was confined to the domestic market, and the focus here is on export-oriented modernization and its impact on natural resources; the Costa Rica case study is extended to all livestock activities; and finally, a new case of agricultural modernization, citrus in Brazil, is included in the analysis.

Grain production in Argentina

The agricultural sector plays a significant role in the Argentine economy for its special importance in gross domestic product (GDP), in exports, in food supply, and in fiscal revenues. Agricultural exports represented 60–68 percent of the total in 1972–87, while grain exports explained more than 90 percent of agricultural exports.

Crops are the principal activity in agriculture, with 63 percent of GDP, while livestock represents 35 percent. The sector shows great heterogeneity due to the large extension of the country and the variety of natural resources, but the pampa region dominates, with a great plain of 45 million hectares, accounting for 75 percent of agricultural production and 75 percent of bovines. The pampa agriculture specializes in cereals and oil seeds, producing 95 percent of domestic output of wheat, maize, sorghum, soy, and sunflower.

Grains (cereals and oils) are the most important line of agricultural production, accounting for 63 percent of total crops in 1985–87. In the period 1960–85, the production of grains experienced sustained growth, which originated in the modernization of the productive process and the parallel growth of services and marketing infrastructure. The volume of production tripled in that period. This growth in production allowed Argentina to recuperate its position in world trade and to produce a record 44 million tons of grains in 1985. However, due to a drastic fall in international prices, production fell to 33 million tons in 1987. The international price recuperated in 1988, but Argentina could not take advantage of it, due to the impact of the adjustment policy and a domestic drought; production decreased further to only 25 million tons.

The modernization process and technology

The fundamental cause of the modernization of grain production was a change in technology: while cultivated land area grew 42 percent in the period, productivity grew 154 percent. Modernization had a significant impact on the economy, increasing exports an equal amount because domestic consumption was stable: in twenty years, the export volume of cereals grew 185 percent and that of oils grew 240 percent.

The technological modernization also generated an increase in the profits in grains that contrasted with a fall in the profits in livestock, and substitution followed. Another notable fact was the continuous increase in the share of oil seeds in grain production from 15 to 47 percent between 1967 and 1987. Differences in the physical characteristics of these products brought important consequences for soils as well as for storage, transport, and shipping.

The axis of the modernization process was the transformation of productive techniques. The evolution of pampa agriculture beginning in 1950 may be characterized by four stages: agricultural techniques, agricultural mechanization, improved seeds, and use of agrochemicals.

The first stage, agricultural techniques, was characterized by research and extension of better agricultural practices. These improved practices were developed basically by the public sector as a result of the creation of the Instituto Nacional de Tecnología Agropecuaria (INTA) in 1956.

The second stage, agricultural mechanization, consisted of diffusion of the use of tractors and mechanical harvesting equipment. Mechanization of the pampa was completed in the 1960s, although growth of the stock of equipment continued in the 1970s, both in number and in power. The mechanization was promoted by a policy with a double objective: protection of domestic production of agricultural machinery and promotion of demand. Protectionist policies included tariff exemptions for materials and equipment, subsidies for domestic production, exemption from sales tax, tax cuts on reinvested profits, and restrictions on the importation of tractors. The promotion of demand was implemented through tax cuts on profits reinvested in fixed agricultural equipment and subsidized credit.

The third stage consisted of diffusion of improved seeds: hybrids, in the case of maize, sorghum, and sunflower, and varieties of Mexican germplasm for wheat, with a massive incorporation of the new varieties taking place in the 1970s. Diffusion of hybrid seeds rapidly increased productivity and made mechanization more profitable. The introduction of Mexican wheat germplasm started in 1972 with the research initially assumed by INTA/CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). Later, private sector development was promoted by the 1978 Seeds Law, which protected genetic knowledge through plant breeder's rights. The new varieties provided a significant increase in yields, but other characteristics were important too: short cycle and ability to respond to fertilizers. Short-cycle varieties allowed double-crop systems, thus contributing to rapid diffusion of the wheat and soy crop. Simultaneously, there was the explosive development of soy, practically unknown until 1960, through a technological package integrated by adapted North American varieties, agronomical recommendations, inoculants, herbicides, and special implements.

The fourth stage, the application of agrochemicals, was initiated in the mid-1970s. Soy, in particular, could not be grown without the new agrochemicals. The private sector took over the importation and distribution of these chemicals, helped by low-duty policies. The use of fertilizers grew in wheat, encouraged by a policy of favorable prices. The Subprograma Nacional de Fertilizantes was established in 1984 to regulate importation by the state, distribution by cooperatives, and a new payment system; as a result, consumption expanded rapidly, increasing fivefold in the years 1983–86.

Macroeconomic and sectoral policies

Macroeconomic policies adopted in the 1950s were influenced by CEPAL's ideas (Comisión Económica para América Latina), notably import substitution industries, considerable state intervention, limiting agriculture to the provision of food and funds, and eventual compensation to the agricultural sector for the extraction of economic surplus.

The principal macroeconomic tools were the exchange rate and tax policy. The exchange rate was officially defined with a strong tendency to overvaluation of the Argentine peso. Export taxes were a traditional tool of fiscal policy, representing 63 percent of indirect taxes and the most important source of revenues. Agricultural export taxes thus became an instrument of industrial development, based on low agricultural prices and on the transfer of economic surplus. Surplus extraction was partially compensated by tax cuts for agricultural firms.

The use of inputs also followed the industrial protection policies: imports of agricultural machinery and other inputs were prohibited or subject to high tariffs, which allowed the development of local industry that, nevertheless, was not competitive and raised the costs for agriculture.

Credit policy also operated as a compensation factor: real interest rates for grains were negative between 1960 and 1977, and the sector was favored additionally by the high share of official banks in the credit supply.

Regarding price policy, the price received by exporters was always lower than the international price, due to the overvalued exchange rate and the export tax. The price received by producers depended additionally on marketing costs and margins. Through the Junta Nacional de Granos and the guaranteed price policy, the state managed to secure the producer price and the internal wheat supply. In general, the trend resulting from variations in international markets and domestic policies was to depress prices.

Despite this clearly biased policy, production and export of grains experienced sustained growth. This paradox is explained by technological innovation. Obviously, actual profit rates and expansion of production were less than they would have been otherwise.

Marketing of grains

The marketing system facilitated modernization. First, grains have a well-developed and competitive international market, are typified, and are not identifiable by brands. Second, since 1930 several mechanisms have developed: arbitrage and warrant systems, official classification systems, and grain quality analysis. The Junta Nacional de Granos has established marketing standards, which are compulsory for the internal market and help to determine grades and price premiums and discounts. All production is negotiated from this base, activating operations and introducing security in the negotiation.

Third, competition exists in the market because the big enterprises' strength was balanced by the Junta de Granos and the cooperatives. However, the Bolsas de Cereales (marketing boards) in the locations of principal concentration allowed competitive markets to form with a great number of suppliers and buyers.

Fourth, international demand and prices evolved favorably during the 1970s, coincident with the period of modernization. The growing development of protectionist policies in the former European Economic Community and the United States, and the virtual commercial war between these two economic powers caused a crisis in international grain prices in 1985.

Expansion was accompanied by transformations in the marketing system. For the handling of grains, in-bulk harvest was incorporated, doubling labor productivity. Likewise, as a result of policy incentives for the domestic production of trucks, the trucks used to transport grains grew in number, capacity, and power, and at the same time a roadway expansion was implemented. Truck transport services were added to railroad services, and transport costs declined 50 percent in real terms between 1960 and 1988. Also, many storage installations were constructed in the 1970s. In summary, the old system of marketing grains, which was characterized by the handling of grains in bags, transport by railroad, and storage in ports, was transformed into a new system of moving in-bulk harvests, transport by truck, and storage in intermediate and private port installations.

Organization of production

The organization of production in the pampa, particularly land distribution and tenancy, has changed significantly since the 1960s. A small decentralization of land was brought about by family enterprises and medium-size capitalist enterprises absorbing growing proportions of land and output. The traditional leasing disappeared in the 1960s, and a new form of leasing, characterized by one-year contracts paid with a percentage of the harvest, was developed. New contractors upgraded their machinery and applied modern technology, looking for the maximum profit for the year.

Backward and forward linkages of the grains productive process were increased or created, strengthening substantially the link between agriculture and industry: no inputs are produced in rural areas today. Everything affecting input prices (exchange rate, tariffs, industrial policies, petroleum prices) affects the agricultural sector, and everything affecting agricultural production levels (climate, tax policy, credit) affects the demand for the providing industries. Greater production of oil seeds stimulated the growth of edible oils and balanced feed industries. The provision of transport, storage, ports, and financing increased alongside agricultural production.

Regarding impacts on agricultural firms, the technological change was accompanied by an increase in long-run profitability. Innovations brought about greater harvest security, greater availability of machinery, and greater resistance to diseases and pests through new seeds and pesticides. At the same time, increases in input use increased total expenses and the need for financing. Technological modernization brought some undesirable aspects regarding soil conservation: the substitution of agriculture for livestock activity and the adoption of double-crop schemes led to the possibility of having a continuous growing season and to the loss of traditional systems that were appropriate for maintaining physical and chemical soil structure.

Farm management became complex and dependent on extrafarm factors; new requirements for information and economic analysis instruments emerged. The principal function of producer organizations is to defend their interests: the unions (Federación Agraria Argentina) and the cooperatives have tried to mitigate their relative disadvantage vis-à-vis the marketing and financial system.

In summary, one may classify the modernization factors under three categories: decisive, facilitating, and discouraging. The decisive factor was a sustained process of generation and incorporation of technology. The facilitating factors were favorable market conditions, the land property and tenancy structure, and decreasing transport cost. The discouraging factor was macroeconomic policy.

Soy production in Brazil

Many factors were connected with modernization of the production, distribution, and processing of soy. This section discusses the dynamics of the soy modernization process, the policies that benefited the subsector, the technological innovations, the market characteristics (the growth of urban demand and external trade), the organization and management of the productive units, the availability of frontier land, and the development of an industrial sector in the means of production for agriculture. Because the soy complex is integrated, one must also consider the dynamics of inputs, machinery, and agricultural implements, soy milling, and human food and animal feed.

Brazil has been an important actor in the world soy market since the 1970s. That participation is made viable by the fact that Brazilian soy enters the market in the off-harvest period of U.S. soy and has more oil and protein in the grain. Brazil has opted for exporting soy derivatives (cake and oil) in order to capture processing value added and ensure full use of the internal mill capacity. The power of the soy agribusiness in Brazil is revealed by the scale of its exports, which surpass those of the United States even though its production lags behind that of the United States.

The soy agribusiness complex is made of a succession of activities (soy chain), including production of capital goods for agriculture, input industries (pesticides and fertilizers), financing, grain production itself, harvest, storage, transport, transformation, and distribution. Brazilian soy production grew strongly in 1969–77 (a boom period), reaching a volume of more than 18 million tons in 1986.

Soy expansion is reflected in the growth of both harvested area and productivity. Harvested area expanded continuously during 1960–80 but fell significantly in 1981–83 as the size of the harvested area declined in the traditional region. The reactivation of planted area after 1984 occurred due to the extraordinary performance of the central and western region, which can be explained by the sudden appearance of new varieties and by the overcoming of additional problems of diseases, plagues, low seed germination, technological deficiencies, and financial and infrastructure shortcomings.

Decisive factors of modernization

Besides the stimulus of international markets, some favorable conditions for expansion of the crop were the existence of original varieties from the United States that were easily adapted to Brazil's southern region; soy cropping in succession with wheat, which maximizes the use of land, fertilizers, machinery, equipment, storage facilities, and labor; the capital made available to the producer as a result of the official policy of self-sufficiency in wheat; the possibility of total mechanization of production; the expansion of national agricultural industry; the urban demand for more edible oils as substitutes for animal grease; and the generation of technology adaptable to different regions.

Macroeconomic and sectoral policies. The Brazilian development model in the 1980s was based on export promotion with a goal of trade surpluses to cover external debt service. Brazil initiated openness to exports in 1964 with exchange rate incentives and fiscal and credit measures. Fiscal policy was strengthened as an instrument for stimulating exports in 1969, when the export subsidy system was created in an effort to diversify the country's exports. The incentives were aimed not at primary exports such as soy, but rather at exports of manufactured goods.

Macroeconomic policies benefited the domestic input and agricultural equipment industry and the soy processing sector. These policies promoted installation and growth of those industries through tariffs and subsidized credit. For the milling industry, they diminished the price of the raw material (soybeans), facilitated installation with subsidized credits, and allowed duty-free grain imports (drawback system) with the objectives of reducing the unused capacity and increasing the incoming external resources. The policies promoted the use of soy cake by the domestic feed industry, the availability of grains to the milling industry, and the satisfaction of domestic demand for soy oil.

The exchange rate overvaluation in some periods affected soy exports and domestic producers, generating negative effective protection rates for soy during 1977–83. Even when the maximum devaluations were adopted, the soy sector was denied the benefits due to the simultaneous imposition of special export taxes.

The sectoral policy that is most relevant to soy is rural credit. Subsidized credit was readily available to the soy complex up to 1982. A strong reduction of rural credit resources occurred later with the retraction of the principal bank for agriculture, Banco do Brazil. However, minimum price policies for soy were not able to secure internal prices, which were fixed by the international market.

Technological aspects of production. Productivity was relatively high initially and grew over the whole period. When soy efforts were initiated in Brazil, the world-level research had already achieved a high degree of technological results in the biological, mechanical, physical, and chemical areas. These products, including sophisticated technologies, were rapidly transferred to the farm level at rates comparable to those in developed countries. The growing trend of productivity in 1960–88, especially after 1968, occurred as a result of national research and rural extension efforts.

The technical-scientific development of U.S. soy had a considerable influence on Brazil's traditional region. The usual hypothesis is that the modest growth of soy productivity in Brazil is explained by that legacy, which placed Brazilian soy at a very high initial level. In fact, soy production in Brazil started with the importation of U.S. species appropriate for production at a latitude of 30°–35°. However, after 1980 new varieties of long juvenile period were developed in Brazil, which made the crop feasible in low-latitude tropical areas where soy production had been economically prohibitive. These long-juvenile-period crops were less dependent on daytime sunlight (photoperiod): previously, the short tropical days produced precocious flowering and stunted the development of traditional varieties. The initial hypothesis must be revised, therefore, because long-juvenile-period crops represent a distinct technological development and an intellectual breakthrough. The vigorous expansion of soy production in nontraditional areas reduced its exposure to localized climatic problems. In any case, Brazil's soy productivity tended to grow, albeit slowly, in particular when compared to the production expansion curve (soy productivity grew from 1,200 kilograms per hectare in 1960 to 1,717 kilograms per hectare in 1988).

A great part of soy area is exploited using machinery. In the traditional region, mechanization is present in all productive phases: preparing the soil, seeding, harvesting, and ng. Agricultural mechanization in the central and western region is demonstrated by the great increase in the number of tractors in 1975–80.

The subsector market. The market facilitated modernization, and the external market was a decisive factor initially. Soy is an intermediate product and must be processed to become part of the human diet. Basic products are extracted from soy for an ample range of processed foods, such as oil, ham, bacon, sausage, hamburger, pork, poultry, bovine feed, pasta, and many other.

Brazilian exports of soybeans and soy cake go to Europe in particular, and exports of oil follow an oriental route, destined especially for Iran and India. Brazil's installed milling capacity, built in the 1970s, is large, and the domestic supply of grain cannot satisfy it; this inability has created the need to import soybeans.

Soy oil confronts today a strong potential competitor through African palm oil. The African palm, after an eight-year growth period, has an annual productive capacity of approximately 8,000 kilograms per hectare for several consecutive decades, while soy is an annual crop producing around 400 kilograms per hectare of oil each harvest.

Organization and management. The soy complex consists of multiple persons and organizations, including means-of-production industries, agricultural producers, transformation industries, traders, and researchers. The soy cooperatives play an important role in the transformation of rural areas. The cooperatives facilitate the provision of indispensable agricultural inputs, technical assistance, storage, marketing, and industrialization. The majority of producers prefer to deliver their output to the cooperative system; only large producers deliver directly to industries.

Soy is the crop that has adopted the most modern technology, which is due in part to Brazilian research institutions that efficiently provide technology to producers. The producers' administrative capacity was first demonstrated in the south, where the wheat-soy double crop became an efficient agricultural activity through its maximum use of soil and ability to minimize soil erosion. That administrative capacity may also be demonstrated by low production costs: in terms of farm production costs, the Brazilian soy is more efficient than U.S. soy.

In conclusion, external markets, agricultural research, the growth of the processing sectors, and economic policies are the decisive factors of soy modernization in Brazil.

Fruit production in Chile

The production of temperate-climate fruits in Chile has special physical requirements and occurs off-season with respect to the northern hemisphere. Between 1970 and 1987, planted area grew from 60,000 to 150,000 hectares, production grew from 500,000 to 1.5 million tons, and exports grew from $12 million to $527 million, representing more than 80 percent of agricultural exports.[1]

Macroeconomic and sectoral policies

Despite a long inflationary period, after 1974, Chile initiated a new monetary policy oriented to reduce inflation and create price stability. That policy favored the subsector of fruits because economic agents could estimate the profitability of investing in the production of fruits with a degree of security.

On financial policy, the period of controlled credit and negative real interest rates that ended in 1975 benefited agriculture moderately. However, the questioning of private enterprise, the agrarian reform, and an overvalued exchange rate eliminated any motivation to invest in fruits.

The deregulation and financial liberalization period (1976–82) favored the subsector, especially the large and medium producers that could contract foreign debt, which enjoyed relatively low real interest rates. With the return of financial regulation (1983–87), the subsector benefited again from the debt renegotiation programs and from the notorious increase in profitability due to the adjustment policies. The decisive element was the change in credit policy, which allowed irrigation systems and infrastructure to be considered as collateral. In this period, a competitive capital market that extended equal treatment to foreign and domestic capital was strengthened, and state institutions such as CORFO (Corporación de Fomento) and Banco del Estado de Chile became less important than commercial banks in fruit financing.

The exchange rate policy was a decisive factor in the Chilean fruit boom, creating incentives for the expansion of exportable fruits, for which the internal market was limited.

During the period 1976–87, three situations may be distinguished. First, the new 1975–79 exchange rate policy created profitability, allowing competition in the international market, generating profits, great expectations, and business expansion, and allowing fruit plantations to increase. Second, profitability declined in the period 1979–82, which was characterized by inflation and a fixed exchange rate: benefits were reduced due to fixed revenues and increasing costs; fortunately, good prices allowed a high share of production to be exported. Third, the 1983–87 exchange rate policy was designed to overcome the external crisis, establishing an extraordinary incentive to invest in exports: profitability rose and, in response, the area devoted to fruit grew on average 9,300 hectares annually.

The 1976–87 tax regulations established the base for the income tax to be the presumed rent, which definitely favored the subsector. Also, the territorial tax rate was only 2 percent annually. However, direct public expenditure on the agricultural sector declined in the period 1976–87, although there were indirect benefits through roadway development, expansion and adaptation of seaports and airports, rural electrification and telephone development, debt reprogramming, and direct subsidies to private irrigation works.

The tariff policy did not benefit the subsector before 1974 because tariffs were high and affected the import component of production costs. However, the new low-and-flat tariffs benefited the subsector by diminishing the relative profitability of other lines of production.

Before 1974, fixing agricultural prices at levels of low profitability encouraged agricultural producers to seek alternative products, especially those with free market prices; plantations of peaches, plums, apples, and table grapes were first established during that period. When price stability was achieved, fruit investment was further favored because investors could clearly envision the expected benefits.

Regarding employment and wage policy, the production of fruits requires a great deal of labor at the farm level as well as the packing level, particularly for harvesting and conditioning the fruit. The labor cost is favorable to the subsector given rural seasonal unemployment and relatively low wages. This situation is even more favorable when compared to wages in competitor countries (Australia, New Zealand, and the United States). An important aspect is the new labor code that creates labor discipline and makes it practically impossible to strike.

The export promotion policy had four favorable elements: the reduction of export costs, reduction of risk, the facilitation of the export process, and the opening of markets. Export cost was diminished by tariff reimbursement on capital goods destined for the production of exportable goods and also by a 10 percent freight-on-board value reimbursement for small exports. The export process was simplified through institutional reforms in the Central Bank, Servicio Nacional de Aduanas (customs), and Tesorería General (treasury). To reduce risks, the Fondo de Garantía a Exportadores was implemented. Regarding market opening, the state played a role through PROCHILE (Promoción de Exportación Chilena) with commercial offices in Asia, Europe, North and South America, and throughout Chile.

Research and technology

Research in fruits was initiated by the Sociedad Nacional de Agricultura (SNA) and was reinforced by several universities and the Instituto Nacional de Investigación Agropecuaria (INIA) in the 1960s. Research in the 1970s was directed to the introduction and adaptation of species and varieties, the implementation of new systems for handling plants, the introduction of rooting patterns, the management of pests and diseases, quarantine problems, and the detection of residual pesticides.

Fundación Chile, with funds from the state and from International Telegraph and Telephone, participated in the diffusion of new technology: fruit experts from California and New Zealand conducted seminars on production, postharvest, and agribusiness. It also established a pilot plant with experimentation lines, created firms and enterprises that were later handed over to the private sector with technical assistance, and introduced new technologies such as frozen fruits and vegetables, principally for blackberries and strawberries.

CORFO was the first institution to promote the idea that Chile should become a fruit-exporting country and, with the Ministry of Agriculture, made the first official registry of fruit land in 1961. The Fruit Development Plan, which was later implemented, was based on that information. The plan stressed changes in farm management, introduction of new varieties, and help for nurseries, packing, and freezing. The institution continues to assist the production of fruits by offering credit and research through agreements with the Universidad de Chile, Universidad Católica, and the INIA.

Private sector research concentrated on adapting foreign technology to domestic climatic conditions. The technology came principally from California and New Zealand; examples are postharvest techniques such as cold chambers with fast cold and with remote sensors and controlled atmosphere. On the productive side, irrigation technology stands out (such as irrigation by dropping and microaspersors) as well as harvest forecasts, high-density plantations, and variety-species diversification. The Asociación de Exportadores de Chile (ASOEX) is concerned with safeguarding the quality of fruit through a quality verification program.

Markets

Chile is oriented toward fresh fruit markets. Favorable conditions and high levels of competitiveness of Chilean producers have allowed high growth of production and promoted a large number of associated investments such as roads, bridges, and communications (in the public sector) and packing, cold-storage plants, and fruit fumigation rooms (in the private sector).

This growth coincided with the significant expansion of exports; fresh fruits in 1987 represented 87 percent of agricultural exports and 10 percent of total exports. Factors contributing to this expansion were the unsatisfied off-season demand for fresh fruits in the United States and European Community and the commercial efforts of producers and exporters assisted by PROCHILE.

Table grapes and apples together represented 79 percent of fresh fruit exports in 1987, and that share has been stable ever since. The U.S. market increased its purchased volume 4.6 times in the period, while the European Community market increased it more than twenty times. The best expression of Chile's export effort was the successful penetration of the Japanese market in the late 1980s.

An important aspect of the strategy was the incorporation of new species and highly differentiated varieties. Chilean producers are evidently averse to commercial risk. The expansion of varieties brought with it a change in seasonality of sales, with various peak times and extension of the total sale period in each year. The important increase in external sales, especially to the United States, was accompanied by moderate price decreases. However, the value of sales was sustained as a result of the revaluation of European currencies and the response of prices to quality aspects.

Organization of producers and exporters and enterprise development

The most important private institution involved in matters pertaining to fruits is the SNA. To strengthen the negotiating position of fruit producers, the Federación de Productores de Frutas (FEDEFRUTA) was created in 1985. Exporters are organized through the Asociación de Exportadores

(ASOEX), which was created during the 1970s. The exporting agents, with public sector help, have been able to overcome trade barriers in some markets. Export enterprises are now able to manage large volumes of exported fruits, without restricting entry to new firms; on the contrary, production is no longer concentrated in a few large producers.

ASOEX's principal actions have been to defend domestic exports from competition and to confront protectionist measures. In the United States, ASOEX gave impulse to formation of the Chilean Fruit Importers Association, coordinated advertising of fresh fruits, cooperated in opening a Chilean consulate in Philadelphia—the principal destination of Chilean fruits—participated with the U.S. Food and Drug Administration and the U.S. Environmental Protection Agency in a study on sulfur anhydride generators, which are used to conserve fruits in transport. ASOEX participated directly in opening the Japanese market by ensuring Chile's compliance with quality and sanitary requirements. In the European Community, it coordinated the position of the Chilean fruit sector to define import licenses for Chilean apples. Its technical department conducts projects on verifying the quality of fruits, using methyl bromide for fumigation, and controlling residual pesticides on fruits.

ASOEX has been concerned since 1981 with quality norms. ASOEX's specification techniques for pears, apples, and table grapes were used by the Official Chilean Norm no. 1549, which established the terminology and the general requisites for fruits and vegetables. The norm included requirements on tolerances to pesticide residuals, packing conditions, and printed labels with information on quality, variety, caliber, packing date, and net content. The norms and regulations of the Chilean official norm apply to persimmons, cherries, plums, apricots, peaches, nectarines, strawberries, kiwis, apples, lemons, melons, pears, tuna (a variety of prickly pear), and table grapes.

From the entrepreneurial point of view, fruit producers share a number of characteristics. In general, they have a high school education, are medium age, have entrepreneurial experience in other sectors, are newcomers to the business, have great capacity to capture technologies and foreign experiences, are prone to support the need to seek continual training in technological aspects and management, have knowledge of macroeconomic policies and agree with the liberal economic policy applied since 1974, have a cautious attitude toward credit risks, participate in associations, remain in business as long as it is profitable, do not share the attachment that traditional farmers have for the activity itself, are democratic entrepreneurs who make subordinates participate in the process, look for creativity in their personnel, and believe in the importance of delegating functions.

Regarding fruit enterprises, available technology is good, financial resources come from the banking system, services of cold storage and packing are generally provided by the exporter, machinery is readily available, and communications are good. Transport service of inputs and products is contracted. The division of labor is achieved by product, enterprises have a high degree of delegation and controlled targets, the relations between supervisors and personnel are adequate, personnel management is sufficient, staff turnover is minimal, executives are selected by reference, and internal communication is good.

The number of exporting enterprises has increased significantly, while the volume of exports has increased 262 percent. This is favorable to fruit producers because it strengthens their bargaining position. Exporting enterprises are efficient: they are able to reach a large number of countries, and the volume of products sold has increased significantly while prices have declined significantly. The exporting enterprises have built a great number of conditioning and storage facilities. In their negotiations with fruit producers, they use different modalities such as production contracts with free consignment or with guaranteed minimum prices.

Vegetable production in Mexico

Vegetable exports provided 44 percent of foreign exchange inflows in Mexico's agricultural sector in 1987–89, while representing only 1 percent of total harvested area. Tomatoes, onions, pumpkins, melons, and watermelons took more than 70 percent of the harvested area and represented more than 80 percent of the total volume of production; tomatoes were the principal product with an average share of 45 percent. Vegetable exports were on the average 32 percent of total production, the rest being absorbed by the internal market. The volume of vegetable exports increased 136 percent in 1970–87, growing from 757,000 to 1.8 million tons, while the value of exports increased an impressive 270 percent in the period, reaching $601 million in 1987.

The great investments in Sinaloa State (northeastern Mexico) helped to transform agriculture into a highly technical and diversified commercial activity. The activity has found optimum conditions for development, using only irrigation land, mechanization, modern and efficient production techniques, basic inputs (fertilizers, pesticides), and improved seeds. Yields are much higher than national averages, and Sinaloa is now the most important producer of tomatoes, cucumbers, pumpkins, runner beans, eggplant, peas, melons, and watermelons.

Macro and sectoral economic policies

Up to 1980, the search for food self-sufficiency weakened agricultural exports. This policy inflated internal agricultural prices, increased direct state participation, and provided assistance in input supply, credit, insurance, marketing, and irrigation. However, the response of agricultural producers was insufficient, imports grew, and self-sufficiency in basic grains was lost.

The 1982 crisis brought a decrease in per capita income, deterioration in real wages, and accumulation of the external debt. The new policy froze agricultural prices, increased agricultural financial resources as compensation, created the Sistema Alimentario Mexicano (SAM) to maintain guaranteed prices, increased public investment, and lowered export taxes.

The government defined a stabilization policy that included fiscal adjustments, increases in public sector prices, decreases in agricultural subsidies, export promotion, trade balance equilibrium, elimination of exchange rate overvaluation, and liberalization of external trade. The wage policy was key in the strategy to curb inflation and achieved a significant fall in the real wage with some social unrest; the concentration of income, which was already acute at the beginning of the decade, increased even more, inflation reached a record three-digit level in 1986, and private and public investment registered very low levels. The crisis affected both the rural and the urban populations, and campesinos saw the wage component of their income decline.

The exchange rate policy initiated in 1982 sought to promote exports, which benefited vegetables: from 1982 to 1987 exports grew from $230 million to $601 million. However, according to U.S. import statistics, export sales of vegetables were much larger than those recorded by Mexican official statistics. This means that the exchange rate controls and distortions propitiated subvaluation of exports as revealed by a study conducted by the Unión Nacional de Productores de Hortalizas (UNPH) in 1983. When exchange rate distortions disappeared in 1985, official exports increased substantially.

Taxes affecting the subsector were the import tax to inputs and the export tax. The fiscal revenues derived from vegetable exports for the period 1970–88 reached $350 million, averaging $22 million annually, but the export tax rates declined.

In 1970–82, the policy was one of compensating the agricultural sector through subsidies. The most important subsidies were the financial subsidy and the subsidies on fertilizers, fuels, and water. In 1982–88, the new stabilization policy substantially reduced subsidies. In 1985, agricultural interest rates were raised to equal bank costs, the subsidy on fertilizer was annulled, and price increases on electricity and fuels were in effect.

Financial policy objectives in 1970–87 were to promote agricultural production, to capitalize productive units, to help small agricultural producers, and to promote basic products. Credits to Mexican agriculture came from the state and the commercial banks. Bank credit figures show that agriculture was the productive sector most hurt by the contraction of credit in the 1980s.

As a result of the Mexican government's effort to promote food self-sufficiency, vegetable producers confronted expensive and scarce credit for production and export. Financing of agricultural exports was reduced in 1977–82. The Banco Nacional de Comercio Exterior handled basically two financing lines—export and pre-export lines—neither was available for vegetables. Vegetable exports grew and consolidated, however, thanks to foreign capital. Within the country, Mexican vegetable producers are considered as high-income producers, which severely restricts their access to bank financing. Another way of financing vegetable production is the so-called agriculture by contract system, which big agribusiness firms use to contract producers and to define the type and quality of the product. The contract establishes the firm's agreement to supply the producer with credit and technical assistance and to buy his output.

Technology policy

Technological policy in Mexico is oriented toward the search for higher yields for basic crops. Research in official institutions was dedicated exclusively to achieving greater productivity of basic grains in response to food self-sufficiency principles, and the federal government dedicated resources to research, technical assistance, and training of grain producers. Vegetables technology has remained in the hands of the producers' own organizations; the state has only made scant efforts to support the production of tomatoes and onions. Notwithstanding, export agriculture has been able to incorporate technical innovations, use improved seeds and agrochemicals, and achieve the highest degree of mechanization.

Modernization implied investments in irrigation infrastructure, an intensive use of inputs, and a change toward greater articulation with the economic process at the national level. Vegetable producers developed a productive process significantly different from that of traditional agriculture, producing exportable products and using irrigation, mechanization, and modern inputs. They were the most benefited by the subsidies for modern inputs. However, intensive input use did not imply parallel increases in production, because the subsidy policy did not promote prudent use of inputs and inputs were misused due to lack of adequate training.

The greatest technological advancement was observed for natural resources management, inputs, genetic advances, and use of pesticides. Regarding water resources, the technology was oriented toward control and storage for later use in planted areas; regarding soil and water conservation, the technology was oriented toward controlling drainage. Research in vegetables and fruits was directed to citrus, bananas, mangos, avocados, papayas, pineapples, guavas, tomatoes, chilies, watermelons, melons, garlic, onions, and pumpkins, and this research focused on genetic-improvement technology (hybrid development, virus-resistant varieties), improved yields, soil fertility, harvest and postharvest techniques, and plagues. The assistance was given by the Instituto Nacional de Investigación Forestal y Agrícola (INIFAP), although the private sector made some efforts through the UNPH.

Regarding plant sanitation and the reduction of phitosanitary risk, programs were established to inspect, diagnose, and control plagues and diseases that may be introduced into the country. The achievements include the quarantine export treatment, improvement and updating of the pesticides manual, eradication of the Mediterranean fruit fly (the principal limitation on Mexican vegetable exports), and acceptable chemical procedures for controlling specific plagues. Finally, Sonora State was declared a plague-free zone, especially from the Mediterranean fruit fly, thus eliminating the need to fumigate vegetables for export.

External markets

The United States and other industrial countries changed their consumption patterns in the 1980s, substituting natural products for processed foods and opening ample possibilities for Mexico to increase the sale of vegetables and fruits. Accordingly, 90 percent of Mexican vegetable sales are to the U.S. market, and for reasons of proximity and buying capacity, the United States is expected to continue to be the principal market for Mexico. Canada is also important, but the intervention of U.S. brokers as a triangulating element limits the possibilities for Mexican participation in that market. Exports have done poorly in the European market, the problem being lack of knowledge of that market.

Marketing of Mexican vegetables ranges from the integrated way in which distributors and producers together determine varieties, timing, packing and product presentation, and joint-risk financing to the extreme in which the producer decides independently what to produce and, at harvest time, is at the mercy of market conditions and brokers.

Lack of commercial innovation in the marketing of Mexican vegetables has encouraged competition by other producing countries. However, the possibilities of the U.S. market are still enormous, because Mexican exports are produced off-season and have been broadened by the current North American Free Trade Agreement (NAFTA).

Producers organizations

Commercial agriculture in Mexico specialized gradually in labor-intensive and high-profitability crops. This agriculture is located in the northern part of the country, within the states of greatest capitalist development and labor demand: Sinaloa, Sonora, Tamaulipas, Baja California Norte, Coahuila, and Chihuahua. In those regions, agricultural entrepreneurial organizations are strong and have the objective of promoting and developing their economic activities and negotiating adequate policy conditions. The most representative organization of vegetables producers is the UNPH. It has its own export regulations, and its members are subject to obligations and sanctions and to the application of minimum norms regarding quality, packing, inspection, and marketing.

Flower production in Colombia

Flowers in Colombia are a successful case of a modern agricultural activity that develops backward and forward linkages and that provides evidence of a new entrepreneurial class that reacts to market signals and opportunities through massive investments. Bogotá's savanna has appropriate ecological and economic conditions for growing flowers: altitude between 2,000 and 3,000 meters, temperature between 13°C and 26°C, adequate luminosity and humidity, proximity to the airport, appropriate input supply, and ample supply of labor, especially female workers.

The Colombian economy of flowers expanded until 1980, when production reached 37,400 tons and $101.4 million. A more stable growth phase followed, with production reaching 87,000 tons and exports expanding 8.3 percent annually to $204.8 million in 1983.

More than 200 firms cultivate approximately 2,000 hectares of flowers, the great majority located in Bogotá's savanna. FLORAMERICA, the largest firm, cultivates nearly 200 hectares in diverse locations, which speclialize in different types of flowers. The average firm has 6–8 hectares, and the minimum economically profitable scale seems to be 3–4 hectares.

Technology

The types of flowers most produced and exported are carnations, roses, and pompons. The productive life of a carnation cutting is approximately two years and that of a rose cutting is up to eight years. The first cutting or planting occurs at six to seven months of life, and it is repeated every three to six months, with peaks every semester more or less.

Production costs are high, and technology is complex. Greenhouses, cuttings, irrigation systems, chemicals, labor, packing, and cold conservation systems are needed. Fixed investment is estimated as $100,000 per hectare, which includes greenhouse construction, cold equipment, and irrigation wells. Variable costs are from $120,000 to $240,000 per hectare annually, including labor for plant handling (50 percent), cost and planting of cuttings (20 percent), and postharvest costs (18 percent), principally packing in carton boxes. Productivity is about 2.4 million carnations per hectare, 500,000 bunches of pompons per hectare, and 1.3 million roses or chrysanthemums per hectare.

Flower crops employ between sixteen (pompons and roses) and thirty (carnations) permanent laborers per hectare each year. The subsector employs nearly 65,000 workers, principally women, who receive wages totaling $65 million annually.

Greenhouse and equipment technology and irrigation techniques have been improved locally. The demand for equipment, materials, and technology has allowed local development of an industry of goods and services, while basic research has allowed domestic development of good-quality cuttings, bulbs, and mother plants.

External market

The principal market is the United States because of its proximity. The bigger firms have direct commercial connections in the United States, but small firms operate by means of exporting agents. Every buyer market has consumption peaks in special holidays. In the United States, these are St. Valentine's Day, St. Patrick's Day, Easter, Mother's Day, and Christmas. Wholesale prices follow demand seasons, oscillating between $1.00 per kilogram in July and $10.00 per kilogram in February/March. However, the U.S. market is changing rapidly, and the off-peak demand is growing significantly.

A packed box for export weighs between 12 and 18 kilograms, according to the type of flower. Every 15-kilogram box contains 600 carnations in 50–60 branches of 10–12 sprouts, wrapped in plastic and conserved against excess humidity. A Jumbo 747 cargo plane transports up to 6,000 boxes of carnations. In the export peaks, twenty to thirty daily flights leave Bogotá with flowers, and the normal flow is five to six flights each day. Freight costs are an important part of the cost, insurance, and freight price, and transport cost thus limits the presence of Colombian flowers in the European and Japanese markets.

Colombia has the second place in world exports of flowers, after Holland. The European market, besides having more competitors, is more demanding (requiring phitosanitary certification) and more protected. The natural market of Colombia is the United States, so the size of the U.S. market and its protectionist trends will limit future expansion of Colombian flowers.

Although the U.S. market is more accessible and less protected, the growing Colombian penetration has already originated protectionist reactions from U.S. producers. Thus, the United States has applied the following norms to Colombian exports: General Agreement on Tariffs and Trade (GATT) safeguard clause, compensatory duties, and the antidumping law. The legal and lobbying costs of ASOCOLFLORES in the United States, reaching $2.0 million yearly, could be used instead to promote consumption, with better results for both parties.

Policies

Colombian flower production received specific government help at the beginning, but only after a critical mass of investment, production, and export had been created. PROEXPO (Promoción de Exportaciones) has provided credit since 1970 for fixed investment and working capital. Flowers also benefited from export tax incentives, such as the Plan Vallejo, the CAT (tax credit certificate), and CERT (tax reimbursement certificate).

The Plan Vallejo consisted of exemption from tariffs and nontariff barriers on raw materials, intermediate products, and equipment used in any production destined for export. The plan made viable the production of exportables, reducing costs, providing international competitiveness, and allowing large-scale commercial production of flowers, which, at the initial stages, was very dependent on equipment, machinery, and imported inputs. Presently, in accordance with the Agreement of Suspension of Compensatory Duties with the United States, Colombian flowers do not benefit from Plan Vallejo. CATs were tax-exempt negotiable titles received by exporters as a percentage of external sales. In 1982, CATs were replaced by the CERT, a new incentive conceptualized as indirect tax reimbursements in order to be acceptable under GATT norms. Colombia eliminated the CERT for flower exports to the North American market in 1985. In any case, the economy of flowers benefited more from the export incentives generated by a consistent policy of currency devaluation in the 1980s.

Perspectives and problems

Growth of Colombian flower exports today tends to be constrained by specific limitations of the U.S. market and by saturation, competition, and protectionism. However, there are still some options for reducing costs and increasing exportable production to reduce air freight costs, to build cold rooms and special terminals at the Bogotá and Miami airports, to reduce production costs of cuttings and mother plants, and to reduce costs of packing cartons, fertilizers, insecticides, and greenhouse plastic.

One option is to expand business to other countries such as Costa Rica, Ecuador, or the Dominican Republic, taking advantage of the economic incentives that those countries concede to production for export: lower input costs, provision of imports and labor, and easy access to the U.S. market. Another option is to join with U.S. producers for promotion and advertising in order to give impulse to sales in the U.S. market far beyond recent trends. This approach would perhaps diminish resistance of U.S. producers to Colombian competition.

Shrimp production in Ecuador

Shrimp mariculture in Ecuador was developed mainly in the 1980s: between 1980 and 1988, production area grew continuously to reach 118,700 hectares, shrimp production went from 10,000 to 65,000 tons, exports grew from 8,100 to 52,500 tons, and export value grew from $56.9 million to $387 million. Shrimp exports are today the second largest source of foreign exchange in Ecuador, surpassed only by petroleum exports.

External market

Shrimp are gathered from fishing and are cultivated in ponds. In 1988, fishing production was 1.55 million tons, while cultivation in ponds reached 450,000 tons, although cultivation production is at present increasing more rapidly than fishing production. The most important economies in shrimp fishing in 1985 were China and India, followed by Indonesia, Taiwan, and Thailand. The most important economies in shrimp cultivation in 1988 were China, Ecuador, Indonesia, and Taiwan. Ecuador is the second largest producer of pond shrimp, but its participation in fishing is very small.

World consumption of shrimp is around 2 million tons. The United States consumes 320,000 tons with a consumption per capita of 1.3 kilograms a year. The U.S. demand grew at an annual rate of 8.5 percent in 1980–88, and it is very dependent on imports, with the principal suppliers being Brazil, China, Ecuador, Mexico, Panama, Taiwan, and Thailand. Ecuador's sales to the U.S. market were 50,000 tons in 1988. Japan is the other major consumer, with a per capita consumption of 1.8 kilograms a year, but its principal suppliers are the Asian countries.

Marketing

The large shrimp farms have their own packing plants, but medium and small producers sell their output to packing plants. In packing plants, the shrimp are cleaned, beheaded, classified, packed, and frozen; from every 100 pounds of shrimp, 65–70 pounds of shrimp tails are obtained. Ecuador's principal export market is the United States; until now, Ecuadoran exports entered that market without restrictions, complying with demanding quality norms. Shrimp are transported to the United States by ship, using 40,000-pound wagons with freeze capacity. The trip takes six days from Ecuador to Miami, where the cargo is then transferred to New York and others markets.

The international price of shrimp increased significantly between 1950 and 1970 (500 percent in real terms). In recent years, the cost, insurance, and freight price (Gulf price) has not fluctuated much, tending to an equilibrium level, between $10,000 and $12,000 per ton.

Policies

The most important domestic policies that affected the development of the shrimp subsector in Ecuador were the exchange rate policy, the tax policy, and the credit policy.

The exchange rate policy was traditionally a policy of an overvalued national currency, although this changed in the second part of the 1980s. There was no export tax for shrimp in the period, but rather, to compensate partially for overvaluation of the sucre, a Certificado de Abono Tributario (tax credit certificate) for nontraditional exports was created in 1979 but was suppressed later in 1986. On credit, easy access to financing was available from the Central Bank of Ecuador, the Banco Nacional de Fomento, the Corporación Financiera Nacional, and private banks, with preferential interest rates.

Production

The most important factors of production affecting the development of the shrimp subsector in Ecuador were land, mangroves, water, labor, capital, larvae, and industrial inputs. Regarding land, 120,000 hectares of ponds were reported in 1988, but only 61,000 were actually incorporated into production. These ponds were built in state-owned beach zones (granted under ten-year concessions) and also in highlands suitable for agriculture.

The mangrove, more than a plant or a forest, is an ecosystem with an enormous variety of fowl, mammals, reptiles, crustaceans, fungi, bacteria, and protozoa. The mangrove is a transition zone between the land and the sea; it resists the waves, holds sediments, diminishes the sea's erosive action, and creates soils. CLIRSEN (Center of Remote Sensors Integrated Surveys) reported that mangroves declined from 204,000 to 170,000 hectares between 1969 and 1987, representing a 16 percent deforestation rate. Even though the use of mangroves for shrimp farms is not profitable in the long run, because only 75 percent of total production is recuperated and the soil acidifies, the illegal deforestation of mangroves continues at the present.

The Gulf of Guayaquil's water is of high quality for shrimp cultivation due to its salinity, temperature, and pH, even though the level of insecticides, heavy metals, and sewage water residuals from Guayaquil and other cities has been growing. Another factor that affects water quality is the red tide—algae and seaweeds—that diminishes the oxygen of the ponds.

An estimated 64,000 persons worked directly in shrimp activity in 1988. To that must be added the 120,000 laborers who were dedicated to fishing and the transport of larvae.

In 1988, Ecuador had 1,422 shrimp farms, 75 packing plants, 55 laboratories, and 120 exporting firms, and total investment was estimated at $1,600 million (an average of $13,800 per hectare). Land-moving machinery is important because the ponds must be rebuilt every four years. The pumping equipment is imported, although pipes are domestically produced. Given the incipient road infrastructure, fluvial transport is used for moving materials, equipment, inputs, and shrimp production.

Postlarvae or seeds are captured along the whole Ecuadoran coast. Seeds are marketed by intermediate traders who buy larvae from fishers and transport them in plastic tanks filled with oxygenated seawater. The supply of natural larvae has diminished considerably lately, which has led to the prohibition of exports and restrictions on capture. To overcome this problem, construction of laboratories has been promoted, but the larvae from laboratories are not ideal; many producers consider that they are less vigorous, have a higher mortality rate, and grow slowly.

Balanced feed complement the shrimp's natural diet, based on phito-zooplancton. Ponds are also fertilized with urea or phosphates to assure phitoplancton growth.

Technology and production systems

New technology, adopted by the shrimp farms of superior technical level, has been generated in Ecuador. In these farms, the water quality (temperature, turbidity, pH, oxygen) is controlled, fertilizers and balanced feed are used, and biomass is controlled. But there still are many backward firms, where shrimp mortality is 40–60 percent and yields are low.

There are three production systems in Ecuador: extensive, semi-extensive, and semi-intensive mariculture. In the extensive system, ponds with water and larvae from tides are used, the density is low, and the feeding depends on natural phitoplancton; no fertilizers or balanced feed are used, and the average yield is 600 pounds per hectare. In the semi-extensive system, designed ponds are used with areas up to 20 hectares, larvae come from nurseries with controlled handling and are transferred later to bigger ponds, pumps for water renovation exist, fertilizers and balanced feed are used, and the average yield is 1,195 pounds per hectare. In the semi-intensive system, laboratory larvae are used in greater proportion, ponds receive high levels of supplementary feed, a permanent technical control is employed, and the average yield is 2,200 pounds per hectare.

Dairy livestock production in Costa Rica

Beef cattle for export used to be an attractive investment for Costa Rica up to 1980, as long as U.S. commercial beef consumers saw Central America as a nearby source of inexpensive meat. The expansion of ranching contributed to the conversion of tropical forests to pastures up to the late 1970s, when the real price of beef decreased. Beef production was then reoriented to a dual-purpose activity of producing beef and milk. The modernization of dairy in Costa Rica should be interpreted as a reconversion of the traditional livestock activity to adapt to new market situations.

Dairy in Costa Rica has two independent stages: (1) production of fluid milk at the farm level with two alternative processes: milk-specialized exploitations and dual-purpose exploitations and (2) processing of pasteurized milk and derivatives. Milk production is destined almost totally for domestic consumption: a self-sufficiency policy has been so successful that imports have been almost totally eliminated.

Milk is the second most important commodity in per capita consumption. Milk consumption per capita increased continuously until 1982, declined significantly in 1982–83, and recovered partially in later years. High consumption levels were a result of government programs to distribute milk until 1984.

During 1967–80, milk production grew 5.6 percent annually, and this growth was accompanied by high milk prices, increases in processing capacity, and an actual reduction of yield per animal, explained by the advent of dual-purpose exploitations.

A substantial fall in production occurred in 1980–83 as a result of economic recession. In 1982, the National Plan of Dairy Promotion tried to deal with the crisis through more-efficient productive processes, gathering points near production regions, and important increases in producer prices; growth reached more than 8 percent in 1984. The crisis of the 1980s also brought with it a fall in agricultural real wages, increases in the cost of balanced feed, fertilizers, and pesticides, and a lessening of milk profitability.

As of 1985, the dairy sector exhausted its ability to expand in the internal market and sought to enter new nontraditional export markets. Prices of the principal world producers continue to be much lower than Costa Rican prices. This results both from a greater efficiency and from agricultural subsidies, which have created overproduction and dumping in the international market. Some Central American countries have a domestic price of fluid milk above that of Costa Rica's, but existing tariffs limit those sales. Dairy exports in the last few years were destined to nearby markets such as Panama, Colombia, Dominican Republic, and the Caribbean.

The accelerated expansion of output was the result of a notable increase in the number of productive units as beef enterprises converted to dual-purpose enterprises. Livestock production increased from 44,000 to 52,000 farms, and milk and dual-purpose production grew even more, together representing 67 percent of farms in 1983. Also, the number of heads of cattle increased significantly from 1.7 million to 2.05 million between 1973 and 1983.

Up to 1978, productivity per animal was low compared to that in Europe and the United States. Only in the 1980s did productivity increase significantly due to technological improvements and technical assistance to producers. Today, there is a high degree of mechanization in milk-specialized production, but technology is inefficient in dual-purpose enterprises.

The dairy industry is concentrated in a few enterprises, in contrast to the great number of milk producers. Excess industrial capacity exists, although 50 percent of fluid milk is not industrialized. The expansion of that capacity took place in the 1970s with only one large processing plant coexisting with a number of small enterprises. Today, four large processing enterprises coexist (three of them are cooperatives), and the number of small enterprises has proliferated. However, the largest enterprise controls 80 percent of the market (Cooperativa Dos Pinos). Domestic output is oriented to internal consumption only, which has prohibited more than one processing firm from operating. Fixed costs for entering the market are high: investment in plant and equipment is significant.

Pasteurized milk is not profitable for the industry given the domestic policy of fixing the consumer price, and the industry has to offset this by the prices of derivatives. The most recent aspect of modernization has been the diversification and incorporation of technological improvements that have extended the durability of products. In the 1980s, the new technical processes of ultra high temperature and of vacuum packing (Tetrabrick) improved the durability of the product and favored the expansion of exports.

Economic policy

The economic situation and policies were conditioning factors of modernization. During 1960–88, the evolution of dairy reflected the country's evolution: accelerated expansion until 1980, stagnation until 1983, and recovery until today.

The strong expansion until 1980 is explained by the development of production zones near the markets, with the consequent reduction of processing and transport costs, by the introduction of new, appropriate production areas, by the expanded capacity of processing plants, and by the growth of demand. In the period 1980–83, the stagnation of milk was the result of the fall in real income, inflation, the external debt crisis, the increase in production costs, and the fall in the real producer price as a result of the adjustment policy. This was followed by a period of recovery influenced by promotion of production, incorporation of new milk areas in low zones, and improvements in producer prices.

Milk imports have no tariffs, although nontariff barriers have been applied. Studies on effective protection indicate that in 1980 and in 1986, the implicit protection level on dairy products was more than 50 percent, and effective protection was around 30 percent (adjustment is made for currency overvaluation). Import and export restrictions were added to tariffs after 1979. These restrictions implied total prohibition of imports and donations of dairy products, which are part of a milk self-sufficiency policy. Since that year, authorization from the Ministerio de Economía, Industria y Comercio is required to import powdered milk and from the Consejo Nacional de Producción to import dairy products.

Exchange rate policy in Costa Rica was characterized by a currency overvaluation that led to artificially cheap imports up to 1981. In 1982 a flexible exchange rate was adopted, leading to currency undervaluation and incrementing import costs. This affected the dairy sector particularly for fertilizers, pesticides, and the industry's import component. This contributed to further deterioration of milk enterprises. Even though the currency undervaluation made exports more attractive, the dairy sector in Costa Rica was not competitive at the international level.

Price fixing directly affected the subsector. Within this system, only fluid milk prices were regulated, leaving to market conditions the prices of all other dairy products. Price fixing was implemented through minimum prices to producers and maximum prices to consumers, thus regulating the margin to processing. Price fixing today is based on estimated costs in a "model farm" that reflects a desired degree of efficiency. To these model costs are added a 30 percent producer margin, a 20 percent industry margin, and a 10 percent retail margin, thus reaching the maximum consumer price.

Regarding credit policy, the share of livestock in agricultural financing has varied between 24 and 36 percent. The greater part of this credit is oriented to beef and dual-purpose enterprises, and the proportion for milk activity is relatively low.

Technology

Before the 1970s, the only technological program directed to the dairy sector sought to improve herd stocks and provide technical assistance on phitosanitary control. Since then, concrete efforts to influence the efficiency and capacity of the subsector have been made; these include the Dairy Modules Program, the National Dairy Production Promotion, and the Genetic Improvement Program. Technical assistance today seeks to promote greater yields and reduce costs through improvement of both the herd stock and the use of pastures and forages.

Milk farms in Costa Rica are classified as milk-specialized highland enterprises and as intermediate-low zone, dual-purpose enterprises. On biological practices, highland enterprises have European races (Holstein, Jersey, Guernsey) with two daily milkings and the sale of calves immediately after birth. Intermediate-low zones have a combination of milk animals and dual-purpose livestock (Brown Swiss, Jersey, Holstein, and zebu), in which cows are milked once a day with assistance from the calf.

Pasture fertilization was an extended technological practice in milk enterprises until 1978, when this practice decreased due to higher fertilizer prices. At present, fertilization is uncommon, and use of herbicides for weed control is growing.

Feeding in livestock exploitations varies by zone and by specialization. In the highlands, more balanced feeds are used, and in low zones, more forages and mineral supplements are used. In milk-specialized enterprises, balanced feed, medicines, vaccines, and veterinarian services represent 70 percent of total production costs.

On reproduction and handling of the stock, artificial insemination, controlled mating, impregnation control, and interval between parturitions are used in specialized milk farms. Artificial insemination is used in highland farms in ever greater proportion; in medium-low zones this practice is restricted to productive units with high yield and efficiency. For handling of the stock, most enterprises use animal sanitation (removal of internal and external parasites, vaccination). The mastitis test is made regularly in milk exploitations.

The technology and equipment used in the dairy industry are imported. The 1985 technological diagnosis showed that the equipment was old, particularly for freezing and cleaning, that qualified personnel was limited, and that imported technology was not adapted to local conditions. The industry was not capable of adopting precision equipment such as pasteurizers, centrifuges, and homogenizers or of preserving milk by drying or by sterilization. Finally, the chemical and microbiological quality of raw materials and finished products was controlled, but the equipment in some enterprises did not comply with the requisites of hygiene and quality control.

Institutional organization and entrepreneurial strategy

Public and private organizations in the dairy sector are well developed in Costa Rica. Thus, the producers cooperatives organize production, processing, and marketing of the products. The government and other institutions coordinate and implement technical assistance and the transfer, adoption, and improvement of technology (Ministerio de Agricultura, universities, and international agencies) and dictate policy guidelines (Ministerio de Economía, Consejo Nacional de Producción). Finally, the milk producers associations act as pressure channels for safeguarding the interests of their associates.

Citrus production in Brazil

The citrus complex in Brazil is part of a select group of activities that, within the crisis of the 1980s, managed to maintain a pattern of great dynamics. Exports of frozen concentrated orange juice (FCOJ) increased from $339 million in 1980 to $1 billion in 1989.[2] The Brazilian citrus complex is responsible for 85 percent of the world trade in FCOJ, 98 percent of Brazilian orange juice production is exported, and 881,000 hectares are cultivated with oranges, constituting the largest citrus plantation in the world. The estimated investment in the subsector reached a value of nearly $1 billion for the 1980s, and the Brazilian production of oranges was an estimated 260 million boxes in 1990, with 82 percent originating in São Paulo. The citrus agribusiness complex is made up of three basic subsystems: provision of inputs (machinery, implements, fertilizers), production of citrus, and production of FCOJ, including distribution and marketing.

The subsystem of inputs is formed by multinational enterprises. Even though citrus crops intensively use chemical inputs, tractors, and implements, they represent only a small part of the market for inputs, around 10 percent for pesticides. The second subsystem is formed by nearly 40,000 rural producers, most of them landowners (96 percent). The distribution of producers by size and share of production shows that medium producers (10–100 hectares) dominate the scene. The third subsystem is formed by sixteen FCOJ-processing firms. The industrial activity is definitively the dynamic pole of the citrus complex, generating value added and assuring continuous expansion and participation in external markets.

Orange planting goes back to Brazil's colonial period, but the rapid growth in São Paulo State after the 1950s was characterized by extremely favorable edaphic and climatic conditions. Conditions of soil, climate, precipitation, temperature, and topography make São Paulo the most propitious region; these conditions influence coloration, acidity, sweetness, and maturation period of the fruit.

São Paulo orange production recuperated from a brutal plague of "Tristeza" in the 1950s on a more technical basis and with new more-resistant varieties. Rapid expansion and increases in yield attracted large marketing firms such as Golwin, Cocozza, Citrobrasil, and Fischer. By the mid-1960s, the first juice-processing industries emerged, when São Paulo production reached 24 million boxes of oranges per harvest. With the beginning of the juice industry, the citrus dynamics reached new dimensions, becoming more dependent on the volumes demanded by the international market. After only five years, between 1963–68, FCOJ production reached 30,000 tons, surpassing U.S. production in record time.

The concentrated orange juice industry

Industry had to be situated near the production zone because of the importance of transport costs. The industries foresaw opportunities as a result of climatic problems affecting U.S. production (1962/63 frosts in Florida). Brazilian industry initiated with a FCOJ production capacity nearing 10,000 tons a year in the mid-1960s, and this grew to 47,000 tons a year in 1970. This intense growth continued, and the productive capacity reached 240,000 tons a year in 1976, 585,000 tons in 1980, and approximately 1.2 million tons a year in 1989/90.

Four leading firms in orange juice production—Citrosuco Paulista, Sucocitrico Cutrale, Cargill Citros, and Frutesp—owned 84 percent of capacity and were responsible for 71 percent of exports in 1988, reaching sales of $814 million. New and big investments have been made in the sector lately. The Votorantim group established the Citrovita firm through a $200 million investment concentrated in a 10,000-hectare orange plantation in Itapetininga/São Paulo and development of two FCOJ plants with a capacity of 50,000 tons and 35,000 tons a year, respectively. This new investment will stress the trend toward decentralization.

Markets

The Brazilian citrus complex is strongly connected to the international market, because two-thirds of oranges are destined for industries that, in turn, export 98 percent of the juice produced. However, the world market is also affected by Brazil, because Brazilian exports represent 85 percent of FCOJ world trade.

The principal FCOJ producers are Brazil (51 percent) and the United States (40 percent), with an estimated world supply equaling 1.5 million tons in 1990. Brazil's share in the world market was 30 percent in 1969, 60 percent in 1975, and 85 percent today, thus creating a quasi-monopoly situation. Up to 1983, the United States was the greatest world producer, with 650,000 tons. FCOJ production in the United States has been relatively stagnant since the mid-1970s; however, new plantations, especially in Florida's southern region, were created in recent years. There are approximately 18 million not yet productive trees, equivalent to 34 percent of total U.S. orange plantations.

Orange juice consumption is related to patterns of food demand spread in the postwar United States. Standardization promoted by the media in a consumer society made feasible a growing supply at ever lower real costs, brought about by reductions in the costs of processing, transport, and marketing. This process allowed the market to expand continuously. In the immediate postwar period, world consumption of FCOJ was concentrated in the United States. In Europe, juice consumption became popular only in the 1960s and 1970s.

The United States is the world's second largest producer of orange juice, but it also is the world's largest importer, for a total of 420,000 tons. Consumption is 870,000 tons or 65 percent of the world total, and this corresponds to a per capita demand equal to 27 liters of orange juice a year. Imports from Brazil averaged 94 percent of the total in the period 1980–87.

Fruit juice consumption is becoming stabilized in most European countries but still enjoys a potential for growth; between 1985 and 1987 European imports of orange juice grew 60 percent. This growth must be attributed to promotions favoring consumption of natural products. Japan, Eastern Europe, U.S.S.R., and Asia's newly industrializing countries are little explored markets. In any case, the habit of drinking orange juice is greatly disseminated in modern Japan: consumption of fruit juice per capita reaches 25 liters a year (50 percent being orange juice and 21 percent apple juice), and the growth of consumption accelerated in the 1970s and the 1980s.

Technology, organization, and management

Competitiveness of Brazilian production has been based on the following set of factors: (a) adequate climatic conditions in citrus plantations, (b) low production costs principally for labor and land, (c) technically modern industrial installed capacity, (d) technical-agronomic development, and (e) a well-structured productive chain incorporating rural producers, industries, transport, and marketing.

The cost advantages are related to economies of scale in production and marketing, technology, and access to raw materials. The modernization of Brazil's citrus complex shows the dynamic of its cost structure, especially the logistic of transport. Until 1982 juice was transported using barrels that were difficult to handle, expensive ($33 per unit of 268 kilogram capacity), and impossible to reuse. The transport cost in a new in-bulk system using special ships and port terminals may be less than half the cost in the barrel system, depending on the scale of operation. The economies of scale provided by the new logistic work fully when the 40,000-ton mark is reached.

A comparison of the costs of orange production in the two principal world producers shows that the average productivity in Brazil (403 boxes per hectare) is substantially lower than that in the United States (754 boxes per hectare), but its unit costs are lower as well. The necessary investments in orange plantation in Brazil—up to the time of commercial production in the fourth year—is only 20 percent of the corresponding investment in the United States; labor costs are triple in the United States, and the costs of operating machinery are double. The result is that the variable cost of oranges in the United States is 50 percent higher than it is in Brazil. When new investments are considered and the expected productivity of 1,100 boxes per hectare is achieved, the cost of a box of oranges will be $1.00 in Brazil, half that in the United States. The comparative advantages of Brazilian production are undeniable; even if labor and machine operation costs were to increase in the long run, the costs of chemical inputs may be reduced via trade liberalization policy, thus maintaining the competitiveness of Brazilian production.

According to projections of the Food and Agriculture Organization of the United Nations, the world market will confront decreasing prices because supply will grow faster than demand and a minimum producer price of $1.45 per box of orange is projected for Although this minimum price will still be higher than the variable cost ($1.00 per box) of the high-efficiency Brazilian citrus projects, U.S. competitiveness will be helped by tariff barriers that provide U.S. producers with an advantage. The question is whether and to what extent society will be willing to subsidize its producers to guarantee a viable citrus industry; the hope in Brazil is that in a context of high fiscal deficit the U.S. position in the GATT Uruguay Round will continue to favor a reduction of subsidies and tariffs.

Resource deterioration in Latin America

This section documents the impacts on natural resources brought about by the economic performance of the selected agricultural subsectors of some Latin American countries. The analysis of the case studies considers two components: (a) identification and description of activities with greater potential to produce environmental impacts and (b) concise evaluation of the environmental impacts generated.

The environmental assessment that was conducted to identify some common impacts on natural resources and the environment produced the following classifications of modernization processes: (a) modernization processes with strong effects on deforestation (soy in Brazil and livestock in Costa Rica), (b) modernization processes with a significant impact on basic agricultural resources (soil deterioration for Argentina's grains, water depletion for Colombia's flowers), (c) modernization processes with significant effects on chemical pollution (Chilean fruits, Mexican vegetables, and Brazilian citrus), and (d) modernization processes with strong impacts on wetlands (shrimp in Ecuador). A summary of the environmental assessment according to this classification follows.

Soy in Brazil

The productive activities of the soy subsector in Brazil that have particular relevance for the environment are related to the preparation of land, planting, cultural practices, and harvest at the agricultural level and to milling and the industrial production of edible oils at the agribusiness level.

The environmental impacts center on the rapid evolution of the crop in the central and western region in the 1980s. The vertiginous growth of soy-planted area in this region contrasts with the decreasing trend in the traditional crop-growing region beginning in 1980. However, this increase in area is explained not by the substitution of soy for other crops but rather by the expansion of an important agricultural frontier based partially, at least, on deforestation of the region south of the Amazon Basin.

The tropical forests of this region are highly vulnerable to serious, irreversible deterioration as a consequence of poorly planned agricultural activities. Direct and indirect impacts of deforestation and colonization of the tropical forest include loss of biodiversity, loss of fragile soils, fragmentation and loss of habitats, social and cultural conflicts with indigenous populations, and climatic repercussions at the world level. In addition, the use of agrochemicals and the growing industrial production of edible oils are causing as yet unknown effects on the quality of water of the surrounding region and on the fauna.

Livestock dairy production in Costa Rica

Economic activities with significant environmental impacts precede the production of beef and milk. The most important processes are the clearing of land and handling of soils (see also chapter 9 in this volume). Clearing of land is related to the conversion of tropical forest to pastures. Handling of soils entails irrigation and drainage, the use of fertilizers, and the production of pastures and grain and forage.

The environmental impacts center on the expansion of ranching, which has contributed—alongside other factors—to the conversion of tropical forest to pastureland in Costa Rica. The result was a steady increase in the number of cattle in the 1960s and 1970s, which stabilized in the late 1980s, and a parallel increase in the amount of pastures and a decrease in forest area.

The process of settlement of cattle ranching has been clearly described by Nations (1985) as reported in Collins and Painter (1986): "Although the causes of deforestation in Middle America are complex, the major forces of destruction can be narrowed to three: logging, colonization, and export crop production. Usually the three factors work in tandem. Logging companies bulldoze roads through tropical forests to extract valuable hardwood trees; landless peasants use these roads to infiltrate into the area and colonize it for subsistence and cash crop agriculture; and finally, either the colonizing farmers themselves or a new group of capital-intensive entrepreneurs clear what remains of the forest to produce monoculture cash crops (cotton, coffee, banana, cacao) or beef cattle."

The deforestation-ranching process in Costa Rica proceeded up to the late 1970s, when the real price of beef decreased. The new situation brought about a reorientation of livestock production from beef to a dual-purpose activity of producing beef and milk.

The dairy sector in Costa Rica presents low negative environmental effects, and it has even been argued that the modernization has somewhat decreased deforestation through the increase in efficiency of livestock production. Industrialization of milk is concentrated today in pasteurized milk, cheese, ice cream, and yogurt. The discharges of residual water from these industrial processes may contain high concentrations of organic materials, solids, and greases and may diminish the level of oxygen in water, but this effect has not been quantified.

Grains in Argentina

Production of grains in Argentina has four basic phases: handling of soil, planting, growth, and harvest. Besides, two types of agents may be distinguished: owners who manage the production directly and lessees who are under one-year contracts and pay a fixed percentage of the harvest. The contractors have their own machinery and apply the best available input-intensive technology.

Planting and growth have required changes in pesticide use at the qualitative and quantitative levels. There have been new plagues and an increase in perennial weeds, which are more costly to confront. These practices require efficient, strong, and concentrated new chemicals that may pose great pollution risks.

The environmental impacts are caused mostly by a profound transformation of the traditional production system, which consisted of rotating cattle grazing with crops and having the livestock activity be the source of renovation of soil fertility. This scheme was replaced by a continuous-crop system.

The contractor was an important factor of modernization, but his mode of production increased the environmental problems by hindering land fallowing and the recuperation of soils. Continuous production and intensification of land use have caused soil degradation, loss of organic material, nitrogen, and phosphorus, and a moderate-to-severe erosion in great extensions of the Argentine pampa with incalculable repercussions. The increased use of fertilizers in the grains subsector may be a proxy variable for this process.

Besides, soy development was characterized by the growing use of agrochemicals (herbicides, fertilizers), although the effects of the intensive use of agrochemicals on water quality have not yet been evaluated.

Flowers in Colombia

The phases in flower production are preparation of land and garden beds, planting and cultural practices, and harvest; within these phases, the activities of greater environmental relevance are stated below.

In land preparation, irrigation systems and infrastructure constitute the activities with the most environmental effect, especially because irrigation requires the perforation of deep wells. In the preparation of garden beds, the soil is sterilized using chemicals. After planting, cultural practices include intensive use of irrigation water and of fertilizers and pesticides for crop control as well as occasional pruning to generate large organic residuals. The labor-intensive harvest involves especially women, and packing requires chemicals to guarantee conservation of flowers. For some products, the crop must be totally dismantled after the harvest, generating important quantities of organic residuals.

Flowers have had important environmental repercussions for Bogotá's savanna. The intensive use of water has caused a worrying depletion of the level of the underground water table. This situation has already created conflicts in the use of water, affecting not only flower producers, but also the residents of urban areas. The problem is aggravated by the fact that the water-bearing zones of the savanna are being subjected to deforestation and urban expansion. Besides, the soils of the savanna will probably experience salinization in the near future.

Agrochemicals and preserving compounds have polluted the phreatic water and also the surface water, even though growers have made some efforts to reuse the water. The effect of this pollution has not been quantified, but the use of female labor has raised serious concerns about the exposure of workers to toxic products. Finally, the construction of greenhouses and sheds has substantially modified the savanna's landscape.

Fruits in Chile

The principal phases in fruit production are land preparation, planting, cultural practices, and harvest. The most sensitive activities for the environment follow.

In land preparation, the terrain must first be adapted, and the most adequate irrigation system must be established, followed by deep plowing, raking, and subsoil breaking. Pesticides and fungicides are commonly employed at planting time to avoid diseases in the root system and in the upper part at pruning time, and the soil is fumigated against fungi, bacteria, and nematoids. After planting, nitrogen fertilization is required as well as an ample range of specific herbicides, because manual control of weeds has become obsolete.

Regarding environmental impacts, the absence of conservation practices has caused a deterioration of the soils. Erosion is not significant (low-slope zones are used for fruits), but salinization does occur due to the irrigation system. The increased use of pesticides is particularly notorious, and pesticide imports have grown in the last twenty years. Even though the environmental impacts have not been evaluated, important distortions in water and soil and yet unknown effects on the fauna are presumed. At present, specific resistance to some plagues and pesticides have developed, which, in turn, makes a greater use of these inputs foreseeable.

Vegetables in Mexico

The principal phases in vegetable production and the most sensitive activities for the environment are similar to those in the case of fruits in Chile: land preparation, planting, cultural practices, and harvest.

On environmental impacts, fertilizers and herbicides are important in the cost structure of vegetables in Mexico. Pollution caused by pesticide use may be especially important in response to the stringent quality requirements of the U.S. market. Aspects to consider are the pollution of water in basins and the repercussions on human health. Studies on pollution caused by pesticides in Mexico's rural areas are in the first stages of implementation, and it is not possible to quantify the magnitude of toxic residuals in the water. All that can be done now is to document the present consumption of carbamates and copper, which is currently 9,000 tons of active ingredients a year and growing at rates between 7 and 15 percent a year.

However, regarding impacts on human health, dangerous levels of fourteen pesticides are currently recorded in the maternal milk of Indian mothers in the State of Sonora (northwestern Mexico and close to Sinaloa). At least eight of these pesticides are included in a "black list" by the United Nations and are legally prohibited in Mexico. Among the pesticides being reported are DDT (which produces cancer, mental retardation, hepatitis), lindane (cancer, sterility), heptacloro (cancer), aldrin (cancer, fetus damage), BHC, dieldrin, and endrin.

Citrus in Brazil

Production of frozen concentrated orange juice in Brazil has three basic phases: initial investment in orange plantations, operational costs of growing and harvesting oranges, and industrial production of FCOJ. The most important investment costs are in land preparation and tree planting. The most important operational costs of maintaining 1 hectare of oranges are pesticides (36 percent) followed closely by fertilizers (32 percent).

The environmental impacts center on the use of chemical pesticides and fertilizers, which is notoriously high in orange plantations and growing fast. The statistics of total national consumption of pesticides for 1981–88 show a strong upward trend, and it is estimated that 10 percent of the total is currently consumed by the citrus subsector.

Shrimp in Ecuador

Four phases are present in shrimp production: infrastructure, soil handling, planting, and growth and harvest. The most sensitive activities for the environment follow.

Construction of infrastructure implies clearing, burning residuals, leveling land, and building pool walls, roads, adduction canals, drainage collectors, fluvial ports, and pumping systems. Soil handling is permanent because after each harvest the terrain must be dried, lime and fertilizers must be added, and the pool must be filled with water for a new planting. Planting is made using natural or laboratory larvae; and in the growth phase the operations are the control of density and average weight, complementary feeding, and water renewal. These cultural practices require adequate handling of water and efficient drainage.

The environmental interactions of shrimp farming are complex. Mariculture development in Ecuador involves the outright destruction of mangroves in an important area of the Pacific Coast. The wetlands and mangrove ecosystems have a high biodiversity, and the consequences of their loss are difficult to quantify. In particular, natural reproduction of shrimp has been reduced, as well as the availability of larvae for planting. The selective fishing of impregnated female shrimp for sale to laboratories has modified the pattern of traditional fishing, deteriorating the ecosystem's natural productivity even more.

The discharge of residual water to the estuary is another disturbance of the ecosystem, breaking the equilibrium of water nutrients and causing excessive fertilization and sanitary problems for the fauna.

Natural resources and public policy

The general guideline for the discussion should be that the solution to the environmental problems of agricultural modernization is not to reverse the new trends in policies nor to reverse the export orientation of the economies, but rather to face these problems directly. If most environmental problems originate from some economic distortion, such as externalities or common property resources, the proper instruments must be used to resolve these distortions at the sectoral or macroeconomic level.

The environmental impacts associated with agricultural modernization involve important economic aspects, most important of which are related to input prices and their indirect impacts on production costs, profitability, and competitiveness. The case studies showed that market limitations provide private economic incentives to overexploit natural resources and create disincentives to protect natural resources in the development process. These limitations have been discussed at large in the literature, and they include very low or null value assigned to ecological capital, private behavior based on the assumption that natural resources are limitless, and strong distortions between private and social benefits and costs. To these general limitations should be added some problems that are intrinsic to Latin American countries: the 1980s economic crisis and the external debt, which have determined the adoption of a strategy based on the mining of natural resources. Besides, underdeveloped market economies have another structural handicap that hampers their ability to incorporate sustainability of production: the market tends to define a high discount rate, thus undervaluing future income flows in favor of present flows.

The behavior of modern private enterprises regarding the environment may vary according to the type and size of the investment project and the country. The ideal private enterprise is an institution that coordinates the transformation of inputs (natural resources) into outputs using the best available technology and that is motivated by an explicit objective of profit maximization. Unless the enterprise is convinced that the failure to conserve natural resources affects their medium- or long-run profits, environmental protection plans will have low priority and low probability of success. Whenever the impacts refer to common property resources, the private enterprise will try to avoid any responsibility. The entrepreneur will direct efforts to implement natural resource conservation only if he is convinced that the additional investment is needed and that his own benefit is at stake. An environmentally friendly behavior, however, may be induced through appropriate incentives and public policies. Furthermore, the concern with natural resources and the environment could be seen, on the part of the entrepreneur, as a strategy of market participation and of creating a good public image for the enterprise.

Government policies must then promote conservation of natural resources on behalf of society. The policies should encourage private firms to to internalize the externalities. The basic instruments of policy that have been identified as the most appropriate for inducing sustainable agricultural development as well as the expected favorable impact on resource conservation and the environment are listed below.

- *Macroeconomic policies.* A consistent policy of exchange rate devaluation in real terms will make sustainable agricultural investment projects more profitable and the use of imported inputs (primary agrochemicals) less profitable. Also, a policy conducive to low real interest rates will make long-run investments more profitable, thus promoting sustainable projects. A tariff policy of low and uniform duties ("flat" tariff), unbiased against primary activities, will make sustainable agricultural investment more profitable. Finally, application of environmental taxes will provide the resources that are needed to implement sustainable programs.

- *Sectoral policies.* Total liberalization of food prices will make agriculture more profitable, creating incentives for not "mining" rural resources and for promoting conservationist practices. A credit policy that carefully provides specific subsidies on financing sustainable agricultural practices will have an impact on new investment in soil conservation and on investment in perennial, more sustainable, crops. A high price for irrigation water will induce a more efficient use of water, and the elimination of subsidies on fertilizers and pesticides will induce a more rational use of agrochemicals. A policy of granting land titles to medium and small farmers of the region will go a long way toward making long-run investments more secure and profitable, as well as toward inducing producers to conduct a more environmentally friendly business.
- *Social policies.* Public and private education will help to raise environmental awareness and consciousness by people from all population groups. A public policy oriented toward generation of job opportunities and employment will help to reduce anti-environmental activities in the rural areas.

Besides economic policies, a government may take concrete actions to deal with environmental problems brought about by market distortions in economic activities. A list of the actions, measures, and controls that could avoid, minimize, or compensate for the perverse environmental impacts described in the previous section are discussed here, under the following categories: ecosystems, pollution, human health, soil resources, and social conflicts.

- *Ecosystems.* The principal environmental impacts (deforestation, loss of wetlands, loss of biodiversity) may be dealt with using better agroecological zoning, protected reserves, and control of colonization, especially regarding the opening of new roadways.
- *Pollution.* The most important impacts (surface water and underground water pollution, discharges of residual water and solid wastes) may be faced through pesticide regulation, norms and control for fluid residuals, recycling of solid wastes, rationalization of water use, and monitoring of water quality.
- *Human health.* The proposed actions are regulation of the use of pesticides, biological control of plagues, and monitoring of health.
- *Soil deterioration.* The most important issues (erosion and loss of soils, loss of nitrogen and phosphorus, salinization) may be counteracted by crop rotation, conservation practices of soils, appropriate cultural practices, and avoidance of overgrazing.
- *Social conflicts.* The impacts (migrations, disruption of social and family patterns, increased demand for basic services, conflicts in the use of land and water) may be dealt with by environmental education, social assistance, regional development planning, land market regulations, regulation of water use, and titles on land.

As a final conclusion, this study should help with the debate on the scope of win-win strategies that would produce efficient economic growth while minimizing the social cost of natural resource use and environmental degradation in Latin America. The relevant question is how much depletion and degradation may be justified to achieve poverty alleviation and growth (Roe 1992). In fact, there are some arguments that outward orientation and liberalization may achieve economic growth and also resolve environmental degradation. First, inward-oriented policies imply undervaluation of natural resource assets, which is conducive to their overexploitation. Second, outward-oriented policies increase the profitability of agricultural firms and their willingness to accept policies that save on natural resources. Third, policy reform tends to open an economy to information and new technology that can reduce the use of environmental resources. Fourth, decreasing fiscal deficits is also good for the environment because resources can be liberated for monitoring environmental degradation and for investment in pro-environment education. Fifth, the new policy may shift resources to agriculture and natural resource activities and take resources away from other activities with higher incidence of pollution and depletion (heavy industry for instance; Roe 1992). In summary, the opportunities for a win-win strategy on economic growth and a healthy environment are there for Latin American countries to seize.

Notes

1. All dollars are U.S. dollars unless otherwise noted.
2. A billion is 1,000 million.

10

Environmental Impact of Governmental Policies and External Shocks in Botswana: A CGE Modeling Approach

Lena Unemo

The purpose of this chapter is to study the impacts on environmental resource use of governmental policies and external shocks.[1] It focuses on governmental policies that did not have any environmental objectives in mind when they were designed. There may, however, be unintended side effects when the policies are imposed. Such unintended effects may be particularly strong if the markets for certain goods, for example land, are imperfect. The direction and magnitude of such effects depend on two factors: (1) whether the policy interventions influence the price of outputs or inputs and (2) the elasticities of the supply and demand curves.

If, on the one hand, the market for land is perfect, the actors expand production by using land along the marginal cost and marginal product curves. If, on the other hand, the market for land is such that actors expand production until profits from using land are zero, the actors move along the average cost and the average product curves (this may be the case if there is common property use of land and no social rules regulating that use). The marginal cost and marginal product curves have steeper slopes than the average cost and average product curves. If the market for land is perfect, any policy intervention that increases the price of the output from land will therefore result in a relatively *small increase* in production of the output. Similarly, if the market for land is perfect, any policy intervention that increases the price of the input, such as land, will result in a relatively *small reduction* in production of the output from land. If the actors, however, expand their production along the average cost and average product curves, the changes in production created by policy interventions will be larger and will reinforce any unintended side effects.

It is a fact that the real world is imperfect and that markets are lacking for a number of goods and services. It is therefore important when carrying out policy analysis to take as the point of departure the prevailing second-best situation. In this essay, the country that is being studied is modeled as a second-best world, where social and private rationality do not always coincide. The model is applied to the country of Botswana and focuses on the changed land use that is likely to come about given different governmental policies and external shocks.

Environmental impacts of governmental policies and external shocks

In the literature on environmental economics, considerable attention has been given to the issue of market failures. Cases where problems arise from or are aggravated by a failure of political institutions have, however, been more neglected. There can, however, be found many examples of governmental policies, with no environmental objective in mind, that encourage an improper use of environmental resources (for example, trade, tax, and exchange rate policies). An additional factor that may complicate the problem is the institutional structure.

In the last few years, more attention has been paid to the role that different policies might play from an environmental point of view. Several recent studies have revealed that the environmental impact of such policies may be substantial (see, for example, Barbier 1989; Binswanger 1989; Southgate, Sierra, and Brown 1989). These studies offer a review of how the economic incentives look in a certain country or area and discuss their impacts on the use of environmental resources. The studies show that it is important to incorporate considerations about the environmental resources when designing various kinds of policies. The unintended environmental impacts of any policy may, however, be often quite complex and sometimes ambiguous, and the task of designing environmentally sound policies may therefore be quite complicated. What makes the matter even more difficult is the fact that the projected gains of policies, such as the stimulation of economic activity, often in the short run appear to offset the less visible long-run effects created by the misuse of environmental resources.

A shortcoming of the studies that have examined the impact of different policies or external shocks on the use of environmental resources is that the studies have been carried out in a quite partial way. Consequently, it has not been possible to capture the outcome of the policies given that they lead to more substantial reallocations in the economy. Furthermore, when examining governmental policies, it may often be necessary to consider several different policies simultaneously, for example a package of taxes, that may push in different ways.

In the present study, an attempt is made, by using a general equilibrium approach, to capture certain reallocations in the economy that would not be captured in a partial framework. The approach adopted is to construct a computable general equilibrium model (henceforth called a CGE model, which is usually described as an economywide, multisector, and price endogenous model that is based on actual data and solved numerically). By adding environmental data, such a model may provide a tool with which to capture the environmental impacts of different policies.

When dealing with environmental resource use at the national level, one will probably be confronted with the issue of the tradeoff between different kinds of use (and possibly different kinds of problems). The theoretical approach to this problem is to measure the impact on people's welfare of the change in the environmental resource. However, this chapter makes no attempt to measure such welfare effects. Instead, the environmental resource use is expressed in physical terms. This may still be a useful approach, for example to explore whether the incentives created by governmental policies in different fields are consistent with the goals of the environmental policy in the country. The kind of approach may also be used for identifying whether conflicts arise between environmental and other goals (for example, concerning economic growth or income distribution) given different scenarios.

This introductory section has provided a background to the study of environmental impacts of governmental policies and external shocks in an imperfect world. In the next section, a brief presentation is given of the country, Botswana, that will be studied. This is followed by a section describing the main features of the model that have been constructed in order to represent the Botswana economy. In the subsequent section, the policy experiments are presented and analyzed.

Because the model is delimited to include only one environmental resource, the study should be looked at as a first step toward making environmental resources visible at the macroeconomic policymaking level in Botswana. The fact that Botswana is very dependent on its environmental resources emphasizes the need to develop a model within which environmental impacts may be analyzed.

Botswana: Current situation

Botswana became independent in 1966 and has since then been very successful economically.[2] Geographically, Botswana is a landlocked country, bordered by Zimbabwe to the east, South Africa to the south, and Namibia to the west and north. It is semiarid, and the Kalahari sandvelt covers 80 percent of the country's area. In the northwestern part of the country, there are grasslands and small areas of tropical forest, and in the east and southeast, there is scrubland. Higher quality land, more suitable for arable agriculture, is situated in the eastern part of the country. The country has a subtropical climate and experiences recurrent periods of severe drought. Rainfall distribution follows generally a cyclical pattern of seven to ten drought and wet years. The country is very fragile and vulnerable to climatic influences, and it experienced a drought during the years 1981–87 that was the most severe during this century.

About 1.3 million people live in the country, of which 120,000 live in the capital Gaborone. In 1989, 25 percent of the population was living in urban areas, as compared to 4 percent in 1965. Current population growth is around 3.5 percent a year.

The economy

The economy of Botswana is to a great extent dominated by natural resource-based activities. The country experienced an economic real growth that averaged almost 16 percent between 1968 and 1977. This outstanding economic performance was due to the expansion of the meat processing industry and the start-up and development of diamond mining. Because knowledge about efficient production of diamonds was lacking in Botswana, the country cooperated with South Africa. Ownership of Botswana's diamond mining company, Debswana, is therefore divided between the South African company De Beers and the Botswana government.

The economy contracted in 1981 and 1982. This was due to the impacts of the drought on agriculture as well as to reduced world demand for diamonds and other minerals. However, real growth resumed strongly the following years due to the start of production of the new Jwaneng diamond mine. During some of the years in the 1980s, the real growth exceeded 20 percent a year (Economist Intelligence Unit 1990–91). Other important sectors of significance are copper-nickel and coal.

In 1985/86, agriculture and mining together accounted for around 45 percent of gross domestic product (GDP) and between 80 and 90 percent of exports. The economy is therefore relatively undiversified, and mining and agriculture continue to predominate. In the late 1980s, however, the manufacturing sector expanded slightly, while the agricultural sector contracted.

The rapid increase in diamond export revenues during the 1980s enabled the government to finance major infrastructure projects, as well as to carry out improvements in education and health services. The country also built up considerable foreign reserves. Because export earnings rose more rapidly than imports, the overall balance of payments was strongly in surplus throughout the 1980s. Botswana also has a very low level of foreign debt, although the debt increased somewhat in recent years.

Within the agricultural sector, livestock production is by far the most dominant activity. It is estimated that 80–90 percent of the population remains dependent on livestock activities in some form (Economist Intelligence Unit 1990–91). The number of livestock has continuously increased during this century, and there has been an increasing commercialization of the sector. The expansion of the meat processing industry has created a trend toward the concentration of larger cattle herds in order to maximize commercial sales to the Botswana Meat Commission. This has tended to skew the distribution of agricultural income.

Botswana is very dependent on food imports, and about 90 percent of the country's annual grain requirement is imported. This high dependence may partly be explained by the desert or semidesert nature of most of the country, where irrigated crop farming is difficult to promote. Imports are bought mainly from South Africa because of its physical proximity but also because the tariffs of the Sacu region (South Africa customs union) are lower than those of other countries. Crop production has developed very slowly, and the productivity per hectare is still similar to that of the 1930s. Cultivated land in Botswana covers less than 1 percent, although 3 to 5 percent of the total land area is suitable for crop production (see Arntzen 1989).

Regarding the manufacturing sector, the domestic market of Botswana is small, which makes it difficult for new industries to establish. Also Botswana is subjected by the customs union to competition from South Africa, where production is carried out on a larger scale. Another disadvantage is the shortage of skilled labor.

Tourism is also increasingly recognized as an important sector that is needed to diversify the economy. It has the potential to create foreign exchange earnings and may encourage protection of Botswana's wildlife.

In summary, during the 1980s, Botswana's economy transformed itself from a subsistence economy to a commercial export-oriented economy. The exports are dominated by minerals and livestock, and the country's economic development is closely linked to the use of its natural resources. This has placed increased stress on the environment. As a result, the country experiences several environmental problems: overgrazing due to expansion of the livestock sector, water scarcity, threatened wildlife resources, and so forth. Because this chapter focuses on land pressure, the overgrazing problem is briefly described in the following section.

The land pressure

Land pressure is most serious in the livestock sector, where overgrazing is common. Overgrazing occurs throughout the country, and in many regions absolute shortages of rangelands exist. Arntzen (1989) has compared stocking rates (in hectares per livestock units) for grazing land and potential carrying capacity in order to measure rangeland degradation. The potential carrying capacity reflects the sustainable use of land in the long run and is based on field studies concerning the ecosystem's productivity. In some districts, the actual number of hectares per livestock unit is only one-fourth of the number expressed by the potential carrying capacity figures. Even if it is taken into account that these figures are crude estimates, there still seems to be sufficient evidence that widespread overgrazing occurs.

Rangeland degradation used to be concentrated in small districts in eastern Botswana, but today it has also spread to western parts of the country. The bore hole development is claimed to have facilitated the spread of land pressure. Initially, bore holes alleviated land pressure in eastern Botswana but probably contributed to increased land pressure in the more fragile western parts. During drought years, there is normally an increase in cattle mortality. This was also the case during the years from 1981 to 1986. But because the productive capacity of rangelands also dropped during the drought, this did not necessarily mean less land pressure.

There is today an awareness of mounting environmental problems in Botswana. This has resulted in the development of an integrated environmental policy, the National Conservation Strategy. The preparations of the strategy started in 1985, and the strategy was completed in 1990. The government has also taken actions to prevent further land pressure. Despite this, there are not, as yet, any clear signs that the pressure on land from the livestock sector has started to ease.

Direct and indirect incentives for livestock holding

Because this study focuses on incentives, created either by active political policies or by external shocks, and their impact on the actual natural resource use, this section reviews some indirect and direct incentives for expanding the livestock sector in Botswana today and in the past.

Before independence, the Protectorate Administration had a limited impact on land and resource management. Its policies were biased toward livestock development and emphasized quantity over quality. The number of livestock therefore rapidly increased and was not matched by improvements in livestock and grazing management. This presumably contributed to initiating the land pressure. After independence, the Botswana government became directly responsible for many aspects of resource management. Land use planning started in the 1970s, but general economic policies did not incorporate environmental considerations. Resource management has also been very centralized and largely sector oriented and has encountered enforcement problems. This has led to a fragmented and incomplete resource management strategy. Increasingly it has been recognized that the lack of coordination among economic policies has sent conflicting signals about how environmental resources should be used. For example, the price structure encourages expansion of the livestock industry, while land use planning and local projects attempt to make farmers aware of the mounting problems of overgrazing.

The literature on Botswana suggests several examples of how governmental policies have resulted in distorted prices (see, for example, Arntzen 1989; Perrings and others 1988). Some incentives that have encouraged livestock holding, directly or indirectly, are:

- *Input prices.* Various forms of government assistance were given to the livestock sector during the 1970s and the early 1980s. The financial assistance involved subsidization of inputs, provision of slaughterhouse facilities, and provision of extension and research services.
- *Fiscal incentives.* Livestock ownership has also been directly encouraged by the government in different fiscal ways. One incentive has been the ability to deduct investment in livestock. Another has been

the ability to write off losses against income from other activities.

- *Favorable trade treatment.* Botswana enjoys preferential access to the European Economic Community (EEC) market under the EEC Convention of Lomé.[3] Trade is therefore thought to have contributed to land pressure through favorable treatment of beef exports. Food imports have also reduced the domestic need for domestically produced crops and, thus, the use of land for crop production.
- *Grain prices.* Grain prices have been linked to subsidized prices in South Africa, resulting in disincentives to produce grain. Such disincentives encourage households to allocate resources to other sectors, notably livestock, that have comparatively better returns.
- *Labor opportunities abroad.* The South African and domestic urban labor markets have offered opportunities for rural-urban migration with mixed impacts on rural development. On the one hand, migration eases land pressure and provides better income opportunities; on the other hand, it causes labor constraints in the agricultural sector. The group of people that is most dependant on the employment in South Africa consists of young, unskilled labor. Consequently, South Africa employs some of the labor that is needed in Botswana's crop-producing sector, which is much more labor intensive than the livestock sector.

The experiments that are run in the model and reviewed later are to some extent inspired by these incentives as they have been suggested in the literature.

The land tenure system

The impact of land tenure on actual use of resources is a quite controversial issue, and the literature on this topic is at the interface between anthropology and economics. The rules concerning land allocation and ownership may influence the use of natural resources in different ways. Because a large part of the land in Botswana is common property land, the question that rises is whether these resources are subject to such intensive use because of the common ownership per se.

The idea that communally owned resources are destined to be overexploited was proposed by Hardin in 1968 ("the tragedy of the commons"). Hardin reasoned that although there are signs of, for example, deteriorating pastureland from additional stocking, it is only rational for each herdsman to add more animals to his herd because he gains the full benefits of each additional animal while he is sharing the costs of overgrazing (the externalities) with the other herdsmen.

Several case studies of developing countries have, however, shown Hardin's proposition to be inappropriate (see, for example, Berkes 1989). It has also been pointed out that traditional systems based on common properties have managed their natural resources over thousands of years on a sustainable basis. Hardin's model is inappropriate because it is based on the reasoning that the actors in the common area will only meet each other once. In reality, they will be sharing the resource for many years to come, and they know that the quality of the range in the future will depend on their success today in reaching an implicit agreement in preserving it.[4]

Yet many common property resources are in fact suffering from environmental degradation. This has lately been explained as being related to the breakdown of existing common property systems due to disruptions that have originated externally to the community. To quote Dasgupta and Mäler (1990), examples of such disruptions are shifting population, rising population, technological progress, unreflective public policies, predatory government, and thieving aristocracies.

As for Botswana, the impact of the land tenure system on natural resource use is not clear. At independence, 6 percent of the land was private, so-called freehold land, the other 94 percent was almost equally shared between tribal and state lands. Tribal (or communal) land was originally allocated by the tribal chiefs. After independence, the government introduced new forms of land tenure on communal land. In 1968 the control of communal land was transferred to the district land boards (by the so-called Tribal Land Act), which allocated grazing land, arable land, and water rights to individuals, while the ownership of land remained communal.

There have been and still are administrative problems with the Tribal Land Act, because of lack of administrative capacity. The interpretation of the functions of the district land boards has to some extent also been controversial (for example, whether the district land boards should be responsible only for allocating the land or also for determining the form of its use). The boards seem, however, to have become the recognized authority for land use planning decisions and to some extent for land development (today, there are eighteen agricultural districts in Botswana).

In 1975, the government of Botswana introduced the Tribal Grazing Lands Policy, which concerned all land except freehold (private) land. Basically, the Tribal Grazing Lands Policy proposed that tribal and state land were to be divided into three categories: commercial ranching, communal land, and reserve land. Land in the commercial zones was to be leased for fifty years for use as ranches. For communal land, the "traditional" grazing system was to continue. The process of rezoning land proved to be difficult, and in some districts the policy was rejected. A difficulty arose because there existed on the communal land a de facto control of land because of private ownership of bore holes. Thus, a system had already developed in which there was a de facto control of land, which was still considered communal. Another problem in accomplishing a rezoning of land was the existence of multiple or overlapping rights to some parts of the land.

Because of the highly variable system of land tenure within the country, and the inability of authorities to enforce the land reform, it seems plausible to assume that the land tenure system does not function in a satisfying way. In some areas, there exists open-access land due to enforcement problems, and in other areas there are conflicting claims on land. Still, in some areas, the system appears to work well, either because the local institutions that deal with the matter function well or because the private ownership of bore holes is so prevalent that the land reforms have not involved much actual change.

Summary

Given the economy, environment, and incentive structure of Botswana, what is reasonable to expect about the management of the environmental resources, in particular land?

If the world were perfect, implying for instance that the users of land know the long-run carrying capacity of land, and the discount rate is correct (reflecting both the future values of capital as well as of environmental resources), then the environmental resources would be used in an efficient way. Efficient should be interpreted here to mean efficient both in the static and in the intertemporal sense. This might very well mean that resources are seemingly overused, because it may be optimal to invest the rents in alternative uses.

If, however, the world is imperfect, and the land tenure system is such that the private cost of using the resource is lower than the cost to society, then some costs will not be incorporated in the private decisions and *an unintentional overuse* of land will be the result. Then if the political institutions through their interventions increase the returns from using land, the situation will continue to deteriorate. Furthermore, if the economy is subjected to an external shock that changes the terms of trade in favor of the environmental resource–intensive goods, then this will also increase the use of land without adequate consideration about the costs.

It is not reasonable to suspect that Botswana (or any other country) has well-functioning markets for all possible goods and services, that is, the world is imperfect. Therefore, it is important to examine the likely side effects on the country's land use of different policies and external shocks.

A model of the Botswana economy

Most CGE models are intended for quantitative comparative statistical analyses of the impacts of policy changes. Within the CGE model, the repercussions in the economy of policy changes or external shocks take place through changed relative prices (which are endogenously determined within the model). CGE models are appropriate tools to use in an economy with resource limitations, because such models may incorporate substitution possibilities in production, consumption, and trade.

The model of Botswana is that of a small open economy. It is a one-period model, although environmental degradation is a highly dynamic phenomenon. There is, however, a lack of data about when and to what extent livestock productivity responds to deteriorating range conditions, which therefore would render difficult a dynamic approach. The social accounting matrix (SAM) for Botswana from 1985/86 has provided a framework for construction of the model and is used as a data base to be input in the model (the SAM embodies the information normally included in national accounts, but it is organized in a different way). Most of the economic data used in the model were collected from the SAM.

Production

The product supply and factor demand functions of the producers are specified to be consistent with profit maximization subject to a technology constraint. The model has seven producing sectors. These are livestock, crop, mining, meat processing, manufacturing, services, and infrastructure. Each of these is assumed to produce a specific type of commodity.

There are four factors of production in the economy, capital (K), skilled labor (L_{sk}), unskilled labor (L_{un}), and land (D). The model also accounts for the fact that capital in one sector, the livestock sector, has a different composition than the capital in the other sectors. In the livestock sector, the capital stock consists of cattle and thus originates from the livestock sector itself, while in all other sectors capital originates from the manufacturing sector.

The production technology is represented by a two-level function where primary factors generate value added. In the mining, manufacturing, meat processing, infrastructure, and service sectors, value added is a Cobb-Douglas function of capital and skilled and unskilled labor. Value added is thus given by:

$$(10\text{-}1) \qquad VA_i = \delta_i L_{sk,i}^{\alpha_i} L_{un,i}^{\beta_i} K_i^{\gamma_i}$$

where i equals mining, manufacturing, meat processing, infrastructure, and service. Because the production technology is assumed to be characterized by constant returns to scale, the Cobb-Douglas factor share parameters sum to 1.

In the crop producing sector, value added is a Cobb-Douglas function of capital, skilled and unskilled labor, and land. Value added is thus given by:

$$(10\text{-}2) \qquad VA_j = \delta_j L_{sk,j}^{\alpha_j} L_{un,j}^{\beta_j} K_j^{\gamma_j} D_j^{\lambda_j}$$

where j equals crop. All the factors, except land, are assumed to be mobile between the different sectors. Land is assumed to be used in fixed amounts within the livestock and within the crop producing sector. Land is assumed to be fixed by institutional reasons, which is consistent with the fact that the use of land in Botswana to a large extent seems to be determined by the so-called district land boards.

The firms demand intermediate goods according to fixed input-output coefficients, which is a common assumption in CGE modeling.

Production in the livestock sector

The production and factor demand in the livestock sector is modeled in a different way to incorporate the suboptimal use of land. Because the entire discussion in this section regards production in the livestock sector, the subindex "livestock" is dropped regarding factors and factor shares.

For each individual cattle owner, output is assumed to be a function of the individual herdsman's own cattle herd, the land kept in common, labor, and the total cattle stock. That is:

(10-3) $$X_{i,livestock} = f(K_i,\ D,\ L_{i,sk},\ L_{i,un},\ K)$$

where "i" refers to each individual cattle owner. All cattle owners are assumed to be identical.

Output is assumed to be increasing in the four former arguments and decreasing in the fifth argument. This means that output increases by the fact that the herdsman adds more cattle to his herd (as well as more labor and land), but decreases by the fact that the total number of cattle increases, that is, the increase in the total number of cattle leads to a decline in grazing possibilities. By assuming an appropriate form for this function, the first-order conditions for profit maximization may be derived. These are used in the model to compute the factor input in the livestock sector.

The following function was chosen to represent each cattle owner's livestock production:

(10-4) $$X_{i,livestock} = \delta K_i^{\gamma} L_{i,sk}^{\alpha} L_{i,un}^{\beta} \left(\frac{1}{K}\right)^{\varpi}$$

In the function above, the ordinary linear homogeneous production function may be recognized (the Cobb-Douglas factor share parameters sum to 1 as before), but added to this is a component expressing the externality. The bracketed term expresses how the output in the livestock sector responds to an aggregated increased holding of cattle (while D_{land} is fixed).

The first-order conditions for profit maximization derived from this function are, where W is the factor price:

(10-5)

$$\frac{PN_{livestock}\,\gamma X_{i,livestock}}{K_i} - \frac{PN_{livestock}\,\varpi X_{i,livestock}}{K} = W_{cap}$$

$$\frac{PN_{livestock}\,\alpha X_{i,livestock}}{L_{i,sk}} = W_{sk}$$

$$\frac{PN_{livestock}\,\beta X_{i,livestock}}{L_{i,un}} = W_{un}$$

It is important to point out the difference between treating the use of land in this way and assuming that land is used in an optimal way. Land is used in an optimal way if each individual herdsman takes into account both the positive and negative impacts on his own output by increasing his own cattle herd *and* the negative impact on the outcome of other herdsmen created by the total decline in grazing possibilities.

The treatment of exports and imports

As for Botswana, we are dealing with a small open economy, which cannot affect the world market prices it is facing. In the model, this assumption therefore holds for all sectors. In addition, the Armington assumption, which is widely used in CGE modeling, is applied to the model. This means that exports, imports, and domestic goods are all distinct and therefore imperfect substitutes (which may be interpreted as being due to differences in quality). If some product differentiation is not included, the model would generate extreme specialization in production as a result of policy changes. Another reason for introducing product differentiation is that CGE models, often carried out on highly aggregated levels, do not disaggregate products sufficiently.

Imported and domestically produced goods are assumed to be combined according to a CES (constant elasticity of substitution) function, while the aggregate of export and domestically consumed goods is assumed to be a CET (constant elasticity of transformation) function.

Income generation, investment, and consumption

Households are divided into two categories: rural and urban. The household demand for products is determined within the model by the maximization of a Cobb-Douglas utility function subject to a budget constraint. Apart from the agricultural sector, rural households also generate a smaller part of their income from other sectors. There are also transfers from the government to both the urban and the rural households. Along with the consumption decision made (according to constant expenditure shares), the two household categories decide on the proportion of their income that will be saved and invested.

The government receives its income through direct and indirect taxes and from a substantial share of the capital. Government demand for final goods is defined using constant expenditure shares of real government revenue.

There is no separate investment function, so aggregate investment is simply equal to aggregate savings (household savings, government savings, business savings, and foreign savings). Total investment is thus determined by savings behavior and is therefore also a function of the distribution of income among the different agents (if their savings rates are assumed to differ).

In most applied general equilibrium models, the allocation of investments is modeled in a very poor way. For instance, the allocation of investment by sector of destination is often given by exogenously determined fixed shares. In the present model, an attempt is made to model the allocation of investment in a more realistic way by linking it to the relative profitability in different sectors. The investable funds are therefore allocated in proportion to each sector's share in aggregate capital income, that is, the shares are given by:

$$\theta_i = \frac{W_{cap}K_i}{\sum_i W_{cap}K_i} \tag{10-6}$$

where i equals all sectors. This is based on the assumption that if the profitability in one sector increases, more capital is allocated to that sector. An underlying assumption is also that the expected rate of return of investments in any particular sector is given by the average rate of return in that sector. Investment by sector of destination is therefore given by:

$$Z_i = \theta_i(S_{lab} + S_{gov} + S_{cap} + S_{for}) \tag{10-7}$$

where i equals all sectors.

Environmental aspects

A variable capturing the pressure on land is incorporated in the model. It is called stocking rate and expresses the number of hectares of grazing land to number of cattle, that is:

$$\text{(10-8)} \quad \frac{D_{\text{livestock}}}{\text{total number of cattle}} = \text{stocking rate}$$

This measure is another way to express the quantity of land in the livestock sector in relation to the part of the capital that is invested in the livestock sector.

The number of animals that are required to make up the "cattle capital stock" has to be estimated to attain this measure. This is done by using livestock data on the number of animals from the base year and relating this to the capital stock in the livestock sector for the same year. A crude conversion parameter constructed from that is assumed to be constant. The value of cattle may, of course, change, but because the value of land is likely to be highly positively correlated with the former, this simplified measure may be adopted to express the stocking rate.

To carry out a policy experiment, the capital stock invested in the livestock sector is converted into the number of animals needed to attain that capital stock. The new stocking rate for the experiment is estimated and may be compared to that of the base case to determine whether land pressure has increased or decreased.

Macro closure

In equilibrium, the different markets in the economy must clear. In this model, these are the product, factor, and foreign exchange markets and the market for investments. The foreign exchange market is in this model equilibrated according to the rule that the nominal exchange rate is fixed as are foreign savings and that it is the price level that adjusts.

Because only relative prices matter, one good is chosen as numéraire and all other prices are measured relative to it. In this model, where the nominal exchange rate is fixed exogenously, the exchange rate serves as the numéraire.

Data

Most of the data needed in the calibration of the model were obtained directly from the 1985/86 social accounting matrix for Botswana, which have been compiled by the Central Statistics Office in Gaborone. Data obtained from the SAM were the input-output coefficients referring to intermediate demand, sectoral quantities regarding production, exports, and imports, the rate of export and import tariffs, and indirect taxes. The factor share parameters and the shift parameters in the production functions are, with one exception, calibrated in the model.

Additional assumptions needed to be made concerning the data that could not be obtained from the SAM. By assuming a Cobb-Douglas function, the elasticity of substitution between factors has already been set to 1. Assumptions needed, however, to be made about the substitution

Table 10-1. Sectoral elasticities

Sector	*CET elasticity*	*CES elasticity*
Livestock	0.400	0.400
Crops	0.800	0.800
Mining	0.900	0.900
Meat processing	0.900	0.900
Manufacturing	0.800	0.800
Infrastructure	0.400	0.400
Services	0.400	0.400

elasticities between imports and domestically produced goods as well as between export and domestically consumed goods (that is, regarding the Armington elasticities). The rule adopted in the present study was to give sectors that are "less tradable," like services, a lower elasticity of substitution than those that are considered "more tradable." The elasticity of transformation between domestically sold and exported goods was treated the same way. The elasticities used in the base case are shown in table 10-1.

Different values on these elasticities were tested in sensitivity analysis. The parameter w in the livestock production sector expresses how the output in the livestock sector responds to an aggregate increased holding of cattle. This is not calibrated in the model (unlike the other factor shares) and was in the base case assumed to be 0.7.

Data also had to be collected on wages of labor in different sectors (from the Central Statistics Office 1986). Data on the extent of land used in the livestock and in the crop sectors, respectively, and on the stock of cattle were obtained from agricultural statistics.

The analysis of governmental policies and external shocks

The experiments that were carried out were to some extent inspired by the literature survey on the incentive structure in Botswana. The software used in the study is GAMS (General Algebraic Modeling System), which was developed at the World Bank. In particular, the changes in land pressure (that is, the stocking rate) were reviewed. It may be kept in mind throughout the experiments that the potential carrying capacity (which reflects the sustainable use of land in the long run) varied around 12–16 hectares per livestock unit measured at the district level (Arntzen 1989).

The changes in stocking rate were also compared to the conventional measure of economic welfare, GDP, to examine whether these move in the same or opposite direction. The change in income distribution between rural and urban households was also examined.

Table 10-2. A 5 percent fall in the price of diamonds: Environmental and economic indicators

Indicator	*Base case*	*Experiment*	*Percentage change from base*
Stocking rate	9.314	8.172	-12.26
Production			
Livestock	151.774	156.582	3.17
Agriculture	65.342	65.422	0.12
Mining	1,309.738	1,262.279	-3.62
Meat processing	150.243	167.050	11.19
Manufacturing	294.003	287.671	-2.15
Infrastructure	750.522	760.196	1.29
Service	812.631	830.115	2.15
Household income			
Urban	522.669	512.370	-1.97
Rural	357.373	356.483	-0.25
GDP	2,391.550	2,365.592	-1.08

A fall in the price of diamonds

Considering the extensive share in the economy of the mining sector, it is of interest to try to capture how factors influencing the mining sector affect the environment. The first experiment carried out was to change the export price of the output in the mineral sector (which to a considerable extent consists of diamonds). The price of diamonds was assumed to fall 5 percent. The results from this experiment are compiled in table 10-2.

By a fall in the price of diamonds, the land pressure increases considerably. This is explained by the fact that the decreased income from diamond mining generates a lower demand for manufacturing goods. The cost of capital falls and makes it comparatively worthwhile to invest in the livestock sector. The expansions of the livestock and the meat processing sectors are surprisingly large. Land pressure therefore increases with a decrease in stocking rate of as much as 12 percent. There is also a slight increase in crop production in this scenario.

Real GDP, which is defined from the expenditure side with imports valued in world prices, decreases by a little more than 1 percent (1.08 percent). Therefore, as the conventional measure of economic welfare changes in the same direction as the environmental indicator on land pressure, both GDP and the stocking rate decrease. As for the change in income and income distribution, the income to urban households decreases almost 2 percent, while the income to rural households decreases only 0.25 percent. The smaller decrease in rural household income is due to the expansion of the livestock sector, as well as of the cropping sector.

A fall in the price of diamonds with exogenously determined return on capital

A second experiment was run in which the return on capital was assumed to be exogenously determined. That is, the return on capital was modeled as being given from the world market and the total capital stock is endogenous. Given this assumption, the result of an increasing land pressure is reinforced when diamond prices fall. The stocking rate decreases almost 16 percent. In the scenario of an exogenously determined return on capital, capital use increases only in the livestock and the meat processing sector and decreases in all the others.

The cost of keeping the land pressure down

The approach of examining governmental policies may be either positive or normative. Most of the experiments that were run in the present study are positive, that is, they simply ask "what if" questions. But because CGE models may be used to solve optimization problems (they have been used in the past to calculate, for example, optimal taxes in an economy), such models may derive optimal policies for sound use of environmental resources. An experiment was therefore run to examine what is the cost to retain the initial land pressure while the price of diamonds falls. The cost is expressed as an indirect tax on livestock production. It was found that with a constant stocking rate (fixed at the base case level) and a 5 percent fall in the price of diamonds, a tax of 7 percent has to be imposed on livestock production. In this scenario, the livestock sector contracts (and so does the mining sector). The manufacturing sector, which contracted in the first experiment, expands in the present experiment. The incomes to both the urban and the rural sectors fall considerably (2.36 percent and 4.13 percent, respectively, and therefore more than in the first experiment), while GDP falls 0.44 percent (that is, less than in the first experiment).

This experiment only illustrates one way of expressing the cost of keeping land pressure down, which obviously may be expressed in a whole range of different ways.

Table 10-3. Deterioration in the terms of trade: Environmental and economic indicators

Indicator	*Base case*	*Experiment*	*Percentage change change from base*
Stocking rate	9.314	9.555	2.589
Production			
Livestock	151.774	149.817	-1.29
Agriculture	65.342	65.734	0.60
Mining	1,309.738	1,293.975	-1.204
Meat processing	150.243	151.620	0.916
Manufacturing	294.003	293.369	-0.216
Infrastructure	750.522	753.490	0.395
Service	812.631	831.033	2.264
Household income			
Urban	522.669	508.433	-2.724
Rural	357.373	339.413	-5.026
GDP	2,391.550	2,381.856	-0.405

Table 10-4. Elimination of import tariff on crops: Environmental and economic indicators

Indicator	*Base case*	*Experiment*	*Percentage change from base*
Stocking rate	9.314	9.307	-0.07
Production			
Livestock	151.774	151.813	0.03
Agriculture	65.342	64.965	-0.58
Mining	1,309.738	1,308.698	-0.08
Meat processing	150.243	151.047	0.54
Manufacturing	294.003	295.099	0.37
Infrastructure	750.522	750.721	0.03
Service	812.631	813.342	0.09
Household income			
Urban	522.669	523.568	0.17
Rural	357.373	357.343	-0.01
GDP	2,391.550	2,391.474	-0.003

A deterioration in the terms of trade

To examine how a deterioration in Botswana's terms of trade affects land pressure, an experiment was run in which both the price of diamonds and the price of output from the meat processing sector fall 5 percent (table 10-3).

As in the first experiment, where only the price of diamonds fell, the mining and the manufacturing sectors contract. The expansion of the meat processing sector that was experienced in the first experiment is dampened, but there is still, surprisingly, a slight expansion of the meat processing sector. The livestock sector, in contrast, contracts, and there is an amelioration of the land pressure.

Although the environmental situation is better, the incomes to the rural and the urban households are considerably decreased. Real GDP also falls, but by less than in the first experiment. In the present experiment, therefore, the indicators of environmental and economic well-being move in the opposite direction.

Lower import tariff on crop

In another experiment, the import tariff on crop that initially (from the base case data) was 13.8 percent was eliminated. The elimination of the import tariff should link the domestic crop price more closely to the lower world market price, making for a disincentive to produce crops and, possibly, encouraging livestock holding. The results from the experiment are compiled in table 10-4.

The elimination of the import tariff on crops does not result in any drastic changes in any variable. As expected, production in the agricultural sector decreases, and the livestock and meat processing sectors expand slightly. The stocking rate decreases 0.07 percent, which is a very marginal change. Despite these marginal changes, the importation of crops increases 10 percent. Because the Armington elasticity is assumed to be quite high (0.8), this is also what would be expected. Domestic production in the agricultural sector decreases so little because total consumption increases significantly, by 4 percent.

Real GDP is subject to a very slight decrease. Because the change in real GDP is so very small, there is no reason to draw conclusions about its change in direction as compared to the change in the stocking rate. Also the change in income distribution is of a very small magnitude, where the income of rural households decreases due to the contraction of the agricultural sector, and the income of urban households increases.

Quantity constraint on labor

An experiment illustrating a decrease in the force of unskilled labor was inspired by the discussion concerning the economic impact of migrant work in South Africa. The experiment only captured the impact on domestic production and did not take

Table 10-5. Quantity constraint on labor: Environmental and economic indicators

Indicator	*Base case*	*Experiment*	*Percentage change from base*
Stocking rate	9.314	9.452	1.49
Production			
Livestock	151.774	149.850	-1.27
Agriculture	65.342	60.172	-7.91
Mining	1,309.738	1,312.050	0.18
Meat processing	150.243	148.204	-1.36
Manufacturing	294.003	277.453	-5.63
Infrastructure	750.522	743.647	-0.92
Service	812.631	805.737	-0.85
Household income			
Urban	522.669	520.783	-0.36
Rural	357.373	355.671	-0.48
GDP	2,391.550	2,371.050	-1.08

account of the fact that the migrant workers presumably send money back to their families in Botswana. The experiment therefore was not designed to look at the economic impact of labor opportunities abroad but may still to some extent serve a purpose for looking at the environmental impacts. The relatively labor-intensive agricultural sector contracts and the livestock sector possibly expands as a result of a quantity constraint on labor (see table 10-5). In the experiment, the force of unskilled labor was assumed to be reduced 10 percent.

The quantity constraint on unskilled labor makes all the sectors except the mining sector contract. The labor-intensive crop producing sector contracts the most, far more than the livestock sector. The stocking rate increases almost 1.5 percent (that is, land pressure decreases). The relatively capital-intensive mining sector expands because the price of capital is lowered.

GDP decreases, illustrating that the measure of economic welfare moves in the opposite direction to the main environmental indicator examined, that is, the stocking rate. The income of both urban and rural households decreases; the income of rural households decreases relatively more.

To conclude, the experiment does not support the view that the existence of labor opportunities abroad for unskilled workers worsens the land pressure.

Capital inflow

The final experiment carried out illustrates the case when the economy is subject to a sudden inflow of foreign earnings. This may lead to the Dutch disease phenomenon, which has been the subject of many studies. The Dutch disease phenomenon refers to the case when an injection of foreign earnings into a tradable sector leads to a real appreciation of the domestic currency, encouraging a factor movement into the less traded sectors. With the Dutch disease, the traded sectors therefore contract and the nontraded sectors expand.

To illustrate the sudden inflow of foreign earnings, foreign savings is simply increased $100 million (that is, P200 million; Botswana's currency is the pula). This represents 80 percent of the outflow of capital otherwise taking place in order to balance international payments. It also represents about 16 percent of total savings.

The experiment leads to a contraction of the meat processing sector and the mining sector, which both are more tradable sectors, while the manufacturing sector (which is less tradable) expands. In contrast, the agricultural sector (which is more tradable) increases, which would not be expected from the theory of Dutch disease. However, the domestic agricultural sector is quite small in the overall economy, and the symptoms of the Dutch disease seem to be present in the main sectors given a sudden inflow of foreign capital.

Despite the contraction of the meat processing sector, there is an increase in livestock holding, which is due to a factor movement into the less traded sectors. This results in increased land pressure, with the stocking rate decreasing a little more than 2 percent. Real GDP increases 1.2 percent and moves therefore in the opposite direction to the indicator of land pressure. Because both the livestock and the agriculture sectors expand, the income of rural households increases (3.6 percent). Also the income of urban households increases, but by less than that of rural households.

Sensitivity analysis

To examine the robustness of the results, sensitivity analysis was carried out. Since the elasticity of substitution between imports and domestically produced goods (the CES elasticity) and the elasticity of transformation between domestically sold and exported goods (the CET elasticity) were chosen in a quite arbitrary way, they were tested for different values (higher and lower) in sensitivity analysis. Similarly, the parameter in the production function in the livestock sector was modified in sensitivity analysis.

In all the simulations in sensitivity analysis, the change of substitution and transformation elasticities affected the results only marginally. In all experiments, the qualitative results remained unchanged. The results obtained in the base case therefore were fairly robust with respect to the substitution and transformation elasticities.

When the land parameter was (lowered) changed to 0.4, the results changed somewhat more. When diamond prices fall 5 percent, land pressure increases a further 6 percent as compared to the base case scenario. For the quantity constraint on unskilled labor, land pressure is ameliorated by a further 1 percent as compared to the base case scenario. The results regarding land pressure are therefore quite sensitive with respect to the value of the land parameter, which could be expected. That is, the less the output in the individual herdsman's production function responds to an increase in the total number of cattle, the more inclined he is to respond to policy changes.

Conclusions

The most surprising result comes from the experiment involving a 5 percent fall in the price of diamonds. This leads to a considerable increase in land pressure. In fact, according to the model, the stocking rate decreases 12 percent (implying an increased pressure on land resources). In the other experiments, the results are less surprising (and less drastic). A deterioration in the terms of trade eases the land pressure. The elimination of the import tariff on crops worsens the land pressure slightly. Labor opportunities abroad for unskilled workers ease the land pressure. Finally, a sudden increase of foreign exchange to the economy puts a heavier pressure on land.

When only looking at the aspect of land pressure in two out of five experiments, the measure of economic welfare, GDP, moves in the same direction as the indicator for "environmental well-being." That is, at the same time as growth in GDP is negative, the land pressure is aggravated as well. In the remaining cases, GDP decreases along with an eased land pressure or vice versa. This supports the opinion that there is not a straightforward relationship between the growth in GDP and the state of the environment.

There will naturally always remain some uncertainties about the results generated from a CGE modeling approach. This may be due to data deficiency, lack of adequate knowledge about factors other than purely economic ones that are influencing people's behavior, or, perhaps most important, inadequacy of the theory on which the model is based. A disadvantage of using CGE models is that they are very data intensive, although it is also true that the structure of CGE models permits very constructive use of the data. Botswana is outstanding among developing countries regarding data availability. Consequently, the approach easily runs into problems when carried out in other developing countries. Increased use of natural resource accounting may improve the data supply considerably. If the natural resource accounting for Botswana outlined in reports by, for example, Gilbert (1990) and Perrings and others (1988) would in fact result in such modified national accounts, this would, together with the social accounting matrix, make up an excellent data base for the construction of a more elaborate CGE model. Such a model could address more environmental impacts and stock effects than the present one can.

Leaving the difficulties inherent in CGE modeling aside, some more general conclusions emerge from this study. First, CGE models may give, if appropriate data are available or may be generated, some interesting insights and a more multifaceted picture of the changes taking place in the society as a result of policy change. And because the purpose of general equilibrium modeling is to show the net effect of different forces, the approach may help to remove uncertainties about the outcome of different policies. Moreover, CGE models may help to derive optimal policies for sound environmental resource use. Second, it is clear that governmental policies and external shocks together with malfunctioning markets can have considerable unintentional impacts on the use of environmental resources. In the present study, this was in particular so in the experiment involving a fall in the price of diamonds. This confirms the view that it is important to bring environmental considerations closer to economic policymaking.

The results have policy implications for developing countries that are dependent on a few natural resources. In many of these countries, considerable changes in the economic structure are currently taken place through structural adjustment programs. Most of these countries also need to seek assistance through the International Monetary Fund, the World Bank, and other agencies to be able to carry out certain policies. Because the assistance—that is, different kinds of loans—typically are tied to a number of conditionalities, the countries above all strive to comply with these conditionalities. Because environmental issues are not on the agenda, the environmental implications of policy reform are not assessed. To change this pattern, it is therefore important when designing structural adjustment programs (or other packages of policy reform), first, to analyze the country with respect to how the markets for different goods and resources work (if they exist at all) and second, to establish what signals the projected policies will create and how these will affect the use of environmental resources. Based on these findings, actions need to be taken to reduce harmful impacts on the environment. The most evident action is to avoid policies that run the risk of having negative environmental impacts and to choose more environmentally friendly policies. This may, however, be quite difficult because the policies are often designed to address wide economic problems. An alternative action is therefore to design and implement complementary measures that will reduce the negative environmental impacts from the program. This may, for example, involve measures to establish the markets for certain goods and resources that initially are missing or are malfunctioning.

Notes

1. This essay is based on a study that is more thoroughly described in Unemo (1993).
2. The British government established the Bechuanaland Protectorate in 1885. Bechuanaland was ruled by a high commissioner in South Africa, and the protectorate rule had a very limited impact compared to that experienced in other parts of Africa.
3. Botswana, as an ACP (African, Caribbean, and Pacific country) state enjoys free access to the European Economic Community market for virtually all its exports and, under the special provisions for ACP beef exports, is eligible for 90 percent levy rebate facilities on shipments of boned beef up to an annual volume of some 18,916 tons (Chr. Michelsen Institute 1988).
4. They have to expect to meet each other either an infinite number of times or an indefinite number of times, not knowing which will be the final time. See the Folk Theorem in the theory of repeated games (Fudenberg and Maskin 1986; Bojö, Mäler, and Unemo 1990).

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11

Economywide Policies and Deforestation: The Case of Costa Rica

Annika Persson and Mohan Munasinghe

Currently, the economic analysis of environmental issues relies mainly on project-level studies, using cost-benefit analyses and environmental assessments. However, economywide policies (both macroeconomic and sectoral) frequently have much more powerful environmental effects than mere project-level investments. Some progress has been made in identifying the environmental consequences of sectoral policies involving, for example, energy, water, or agricultural pricing. Nevertheless, the impacts of broad macroeconomic reforms (such as exchange rate devaluation, trade liberalization, privatization, and other fiscal and monetary stabilization policies) on natural resource and pollution management are far more difficult to trace. This hampers efforts to design better sustainable development strategies that meet economic, social, and environmental criteria in a more balanced way (Munasinghe 1993b).

In the case of the World Bank, for example, the general lack of knowledge about links between economic policies and the environment has delayed attempts to expand gradually the application of environmental analysis to cover economywide or policy-based lending—the second largest use of Bank resources amounting to about $5.8 billion, or 27 percent of total lending in 1993 (Munasinghe 1993a).[1] It has also hampered efforts to develop more effective national environmental action plans (which are prepared by borrowing countries, with Bank assistance, to help determine priorities for activities that address national environmental issues).

A recent study argues that economywide policy reforms, especially liberalization of prices, are generally beneficial for both the economy and the environment (Munasinghe and Cruz 1994). However, overlooked imperfections such as market failures, policy distortions, and institutional constraints can often interact with the original reforms to cause environmental harm. Thus, it is important for decisionmakers to be able to trace the complicated paths by which macro-level policy changes ultimately affect incentives for efficient resource use at the micro level of firms or households. The objective is not necessarily to modify the original broader policies (which have conventional economic or poverty-related goals), but rather to design more specific or localized complementary measures that remove economic distortions or constraints. These additional measures would help to mitigate negative effects or enhance positive impacts of the original policies on the environment. Such complementary actions would include both market-based approaches (like Pigovian taxes on environmental externalities or allocation of limited pollution rights coupled with marketable permits), as well as nonmarket methods (such as command-and-control techniques) and specific investment projects.

The ideal approach is a general equilibrium analysis that traces both the economic and environmental effects of economywide policy reforms. When such comprehensive methods are not possible in developing countries where data and skills are scarce, partial approaches that help to identify the most important impacts of economywide policies are frequently used. Because the full consequences of a policy are not traced, both quantitative and qualitative results of the partial equilibrium model may be wrong. For example, taxes that are not "lump sum" may carry over from the sector for which they were intended into other sectors of the economy and affect consumption and production decisions there as well. In this context, the main purpose of this chapter is to investigate the effects of economywide policies in Costa Rica on forest areas and the environment (Persson 1994). We also seek to determine whether new measures involving the allocation of property rights to these forests will yield different results when analyzed using a general equilibrium model rather than a more conventional partial equilibrium approach.

In the remainder of this section, the main issues, analytical approach, and results are summarized. The following section describes previous work on Costa Rica and the environmental priorities. The applicability of computable general equilibrium (CGE) models to such problems is discussed next, followed by further details of the model and data used here. Finally, the last two sections summarize the chief results and conclusions of the study. A technical appendix provides more information on the model.

Deforestation and soil erosion are major environmental problems in Costa Rica. Some data on forest clearing over time are shown in table 11-1. To evaluate how sectoral and economywide policies can help to control deforestation, the CGE model used here highlights the economic activities and factors that specifically affect deforestation in Costa Rica. The model goes beyond standard approaches in two important respects. First, it can simulate the effect of introducing property rights on forest resources, thus encouraging sustainable management of forests by private individuals who value future returns to forestry. Second, it includes markets for logs and cleared land: loggers deforest to sell timber to the forest industry and for exports, and squatters clear land for agricultural production and for sale to the agriculture sector as it expands and requires more land.

Table 11-1 Total land area in forests and agriculture, 1963, 1973, and 1986
(percentages)

Sector	*1963*	*1973*	*1986*
Agriculture	30	40	57
Forest	67	57	40

Source: Solórzano and others 1991.

The model retains features that are fairly standard in most CGE models. The tradable sectors—forestry, agriculture, and industry—are price takers in the world market, while infrastructure and services produce nontraded output. To focus on the natural resource sectors, the domestically mobile factors include, aside from capital and (skilled and unskilled) labor, cleared land and logs. The supplies of both labor and capital are exogenous. The demand for these factors arises from the producing sectors (agriculture, industry, and so forth) and from the deforestation activity of loggers and squatters. The supply of "cleared" land is initially based on Costa Rica's total land area that has been deforested. However, additional cleared land is made available from increased deforestation. This rate of land clearing depends on the definition of property rights as well as on taxes (or subsidies) that affect the forest and agricultural sectors. In addition, the expansion of squatting activities augments the cleared land factor. Agricultural production provides the demand for cleared land.

Poorly defined property rights in Costa Rican forests play an important role in deforestation. The model indicates that correction of this market failure would reduce deforestation. If property rights are well defined and the interest rate is exogenous, the value that loggers assign to preserving the forests is crucial. In order to stop deforestation, the benefits from preserving the forests must be significantly higher than the value of the logs and the cleared land.

In the model, tax policies may generate unexpected side effects, and substitution effects between inputs in the producing sectors may be important. Therefore, when possible impacts of macroeconomic policies are investigated, the general equilibrium approach generates results that are different from those derived from a partial equilibrium analysis.

Status of forests in Costa Rica

Deforestation in Costa Rica is proceeding at a rapid pace, and concern about this is growing both inside the country and within environmental organizations in the rest of the world. Ministerio de Recursos Naturales, Energía y Minas (1990) mentions the following economic and ecological benefits that Costa Rica may lose if deforestation continues: access to construction materials and other wood products, unchecked species of plants and animals that have possible and future uses for consumption and industrial production, recreation and eco-tourism, control of erosion and sedimentation, and education and research possibilities. The greenhouse effect and concerns about the rich biological diversity in Costa Rica may be important to other countries and environmental organizations.

Deforestation and erosion are the main environmental problems in the country

(Blomström and Lundahl 1989; Foy and Daly 1989). Originally, most of Costa Rica was forested, but in 1977 only 31 percent (16,000 square kilometers) remained covered with forests. Blomström and Lundahl (1989) estimate that in 1983, 14 percent of the area was still covered with forests. Solórzano and others (1991) give the more conservative estimate that about 40 percent of the land is still covered with forests. This difference is probably due to differences in what types of forests were investigated. The lower estimates probably concern only primary forests, whereas the higher estimates include secondary forests and intervened forests (Sader and Joyce 1988). Most of the deforestation has occurred since 1950. If deforestation continues at the current rate, the commercial forests of Costa Rica will be exhausted within the next five years. The life zones with the highest rates of deforestation are the tropical wet forests; these are also the life zones in which biodiversity levels are highest (Solórzano and others 1991).

Carriére (1991b) describes the process of deforestation as taking place in several stages. First, a logging company involved in highgrading clears a vehicle tract to extract lumber. Thereafter, the road is improved by the government due to pressures from lobbying groups, and this in turn enables local peasant families to clear and use the remaining forest for subsistence agriculture until the decreasing yields force them to sell or abandon the land, depending on whether it is titled or not. However, the land is still suitable for pasture and is therefore assembled by urban-based real estate companies and sold to cattle ranchers. After a few years, the land is almost completely degraded and unsuitable for any kind of economic use. This view is shared by Keogh (1984).

The Costa Rican government is taking steps to preserve the forests. More than 13,000 square kilometers have been designated as national parks, although in the past deforestation was encouraged to diversify the country's production away from coffee and banana crops (Biesanz, Biesanz, and Biesanz 1987).

The following four groups are responsible for deforestation in Costa Rica (Lutz and Daly 1990):

- *The timber industry may be responsible for deforesting as much as 20,000 hectares annually.* Logging requires a special permit from the government, but about half of the trees are cut illegally. Domestically cut logs are processed locally and are used typically in construction. Exports of wood and wood products are small, and imports are negligible.

  The current import tariff on logs is 5 percent (Lutz and Daly 1990). The efficiency in the forestry sector is low, and only a few species are commercially used. About 54 percent of the logs are processed, and of these about half finally reach the market (Ministerio de Recursos Naturales, Energía y Minas 1990). The main part of the logs used in the timber industry are bought from sources other than the industry itself.

- *Banana firms and other companies are expanding their plantations rapidly.* The main products cultivated in Costa Rica are rice, coffee, fruits, sugarcane, beans, maize, and sorghum (Hugo and others 1983). Lutz and Daly (1990) state that erosion is visible in some areas, but that farmers "do not produce in obviously unsuitable ways to destroy the environment. . . . For example living fences are widely used, which reduce erosion, and protective forest cover is left intact next to creeks, on contours or steep slopes, etc."

  The Costa Rican tax structure for income and property taxes is regressive. Sales taxes and other indirect taxes constituted 70 percent of the total tax revenues in 1970, and there are indications that this figure may still be high. Although property taxes are low (in some cases about 1 percent of the actual market value), property and income tax evasion is a problem that costs the country approximately C100 billion a year (Costa Rica's currency is the colón). A remedy may be to raise the price of land by increasing land taxes, to increase tax collection rates, and to prosecute tax evaders more effectively.

- *Cattle ranchers have expanded their activities rapidly at the expense of forested areas in recent decades.* However, this type of land conversion may be limited now because most of the land that can be sustainably used for pasture has already been cleared. In the 1950s and 1960s, there was a large increase in investment in cattle, encouraged by foreign aid and investment as well as government aid in the forms of credit and provision of infrastructure. This increase of cattle ranching caused deforestation to increase rapidly. The pasture trend boomed in the 1970s, but since then profits have decreased. More than 70 percent of the farmland is in pasture, while only 2.5 percent is in coffee and 1.1 percent is in bananas (Biesanz, Biesanz, and Biesanz 1987).
- *Squatting is taking place on both privately owned and government land.* Some of the squatters produce agricultural outputs, but others sell the cleared land to cattle ranchers or other landowners. Buyers who buy "in good faith" from squatters are not prosecuted. About twice as much is paid for cleared land as is paid for forests.

Squatting is an important cause of deforestation in Costa Rica. By clearing the land, it is possible to get formal ownership of it (Blomström and Lundahl 1989) or in some cases at least of the "land improvements." Squatting by smallholders nowadays appears to constitute a less significant part of the deforestation in an overall context, although it may be locally important (Lutz and Daly 1990).

If ownership may be obtained with no costs other than those of clearing the land, the forests can be seen as a type of common property, while the cleared land is perceived as traditional private property. However, in the case of Costa Rica, it is not the traditional case of undefined property rights, where we have an open-access resource (see, for example, Dasgupta 1982). We are here looking at insecure land tenure. This implies that there is no crowding effect on the stock of the resource, which is what occurs when each agent maximizes his own profit without taking into account the effect on the stock of the resource. Instead of the traditional open-access problem, we have a form of short-term property rights when deforestation occurs, but the property rights to the standing forests are not protected. The logger or squatter will continue deforestation only until the marginal cost of deforestation equals the marginal revenue, because of this structure of property rights. The social cost of deforestation will then be higher than the private cost since "the world's" willingness to pay for the preservation of the Costa Rican forests will not be included in the private cost. That the difference in cost functions is a major cause of deforestation in the developing world is shown in Chichilnisky (1993), where a North-South trade model is developed, and the difference in trade patterns between North and South is explained by the difference in property rights. Thus, deforestation would be driven by the difference in private and social objectives. For example, the loggers' main interest may be the profitability of the logging operation itself without much consideration about future, alternative uses of the land.

Another critical economic factor may be the existence of high private discount rates, that is, deforestation may be caused by discounting the future value of the forests. A high discount factor implies that future gains from the forests are of much less value than the gains from deforestation today. The impacts of tropical forests are often more significant in the long term than in the short term. However, the regenerative capacity of tropical forests is low, and the discounting of future environmental benefits may often make it more profitable to harvest forest resources as quickly as possible. Forest investments, like replanting, take a long time to yield returns, and individuals therefore find little attraction in conservation and reforestation activities. In many developing countries, private market rates are very high and often exceed the rate that would be socially justifiable (Barbier, Burgess, and Markandya 1991). Poor people often face even higher discount rates because of credit constraints.

Further, Barbier and Burgess (1994) show that input and output prices in agriculture and cattle ranching have important impacts on deforestation. This suggests that in addition to sectoral policies, economywide policies such as taxation may have a significant effect on deforestation rates.

The modeling approach

As may be concluded from the above, the main reasons for deforestation and thereby erosion are:

- The price of land is too low because the total social opportunity value of the rain forests is not included.
- Undefined property rights make the private cost of deforestation lower than the social cost of deforestation.
- Discount rates may be too high; this implies that the future gains from the forests are lower than the gains from deforestation today.
- In addition, economywide policies such as the tax system may cause deforestation.

Computable general equilibrium (CGE) models have been applied before to environmental problems—mainly issues involving air pollution and pollution taxes. A short discussion of some CGE models relevant to the approach developed here is provided below.

Bergman's (1990a, 1990b) model is designed to simulate the effects of environmental regulation and energy policy on the Swedish economy. The environmental market failure is in this case corrected by the creation of a market for emission permits. The cost of emission permits for carbon dioxide, sulfur, and nitrogen is incorporated in the cost functions.

Jorgenson and Wilcoxen (1990) analyze the economic impact of environmental regulations on the U.S. economy. This is done by simulating long-term growth with and without environmental regulations. The share of abatement costs in total costs is estimated for each industry, as are the share of investment in pollution control equipment and the cost of pollution control devices in motor vehicles. The model is run with and without these costs to estimate the economic impacts.

There are few examples of CGE models dealing with the impact on the economy of overexploitation of natural resources. Panayotou and Sussengkarn (1992) construct a model against the background of environmental problems in Thailand. The sources of the environmental issues are economic growth, exchange rate problems, and government policies (such as agricultural policies and taxation and the land tenure system) promoting deforestation. The approach implies that every unit of production in each producing sector produces, for example, a fix amount of air pollution or deforestation. The environmental impacts are not part of the model per se—the environmental degradation or improvement is not fed back into the model so as to affect future production and consumption decisions. The results include the findings that export taxes on rice and rubber increase investment in soil conservation, increase the use of agrochemicals, and shift land from rubber to rice.

Not much work has been done on the modeling of undefined property rights in a general equilibrium context, where the results may differ from those of a partial equilibrium model. Devarajan (1990) suggests that a fruitful approach may be to incorporate a partial equilibrium model in the general equilibrium framework by first removing the first-order condition that labor must be paid the value of its marginal product in some sectors and then replacing it with a condition that reflects the suboptimal behavior of the sector. This enables an analysis of the effects on deforestation of policy interventions in the system. The model has to be dynamic in order to take account of both the stock and the flow effects of deforestation.

Unemo (1993) models the suboptimal use of land in Botswana that is caused by overgrazing of cattle due to undefined property rights to the land. Land is seen as an open-access resource, and the effects of overgrazing are incorporated in the cattle owner's production function in the form of crowding effects. The quantity of output is determined not only by the number of cattle the individual owns, but by the whole population of cattle grazing on the land. The results include the finding that a fall in the price of diamonds considerably increases pressure on land, as mining becomes less profitable relative to cattle ranching.

In order to model property rights–related behavior in Costa Rican forests, it is assumed that the private cost of deforestation is lower than the social opportunity value of the forests when property rights are undefined. When property rights are defined, the social value of the rain forests is incorporated in the utility functions of the squatters and therefore in the private cost of deforestation. This approach facilitates analysis of the role of undefined property rights and follows the approach used by Chichilnisky (1993).

General features of the model

This model is a static CGE model of an open economy, although it has certain implicit dynamic features because the discount rate is included in the future valuation of forested land. It differs from the standard approach of CGE modeling by the inclusion of undefined property rights and by the modification of the functioning of the markets for logs and cleared land. This is discussed in detail below. Land cleared by squatters is assumed to be sold to the agricultural sector.

The model has two types of sectors. The tradable producing sectors (*T* sectors)—forest, agriculture, and industry—are assumed to be price takers on the world market in the standard Heckscher-Ohlin fashion. The nontradable producing sectors (*N* sectors) are infrastructure and service.[2] In addition, there are two sectors that clear land. Loggers clear land for the purpose of obtaining logs for the forest industry and for exports, and squatters clear land and sell it to the agriculture sector.

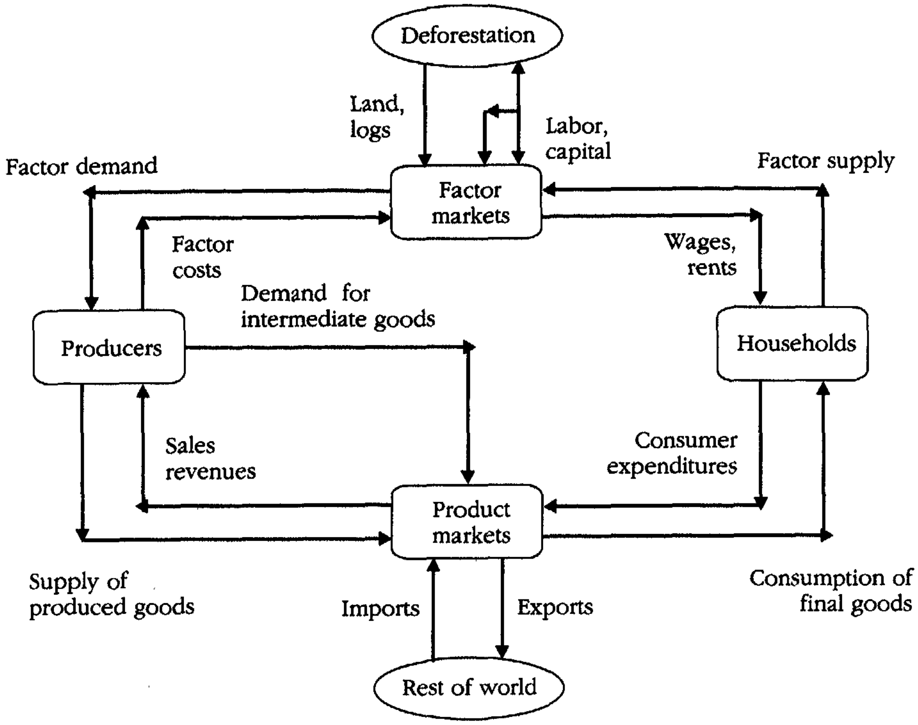
The domestic intersectorally mobile production factors are unskilled labor (ULABOR), skilled labor (SLABOR), and capital (CAPITAL). Logs (LOGS) and cleared land (DLAND) are specific to the forest and agriculture sectors, respectively, although logs can be traded on the world market. No reafforestation is possible in the model.

The key elements of the CGE model are introduced below. A more detailed mathematical description is given in appendix 11-1.

Factor market equilibrium and the stock of forested land

The supplies of both labor and capital are assumed to be exogenously given, and for factor markets to clear, these supplies must equal the demands for labor and capital, respectively (see figure 11-1). Demands arise from the producing sectors plus the amounts used for deforestation by squatters and loggers. The demand for each production factor (like capital or labor) within both the *T* and *N* sectors as well as the deforestation sectors is given by the partial derivative of the cost function for the relevant sector with respect to the price of the same production factor. Both loggers and

Figure 11-1 Graphical representation of flows in the model: main linkages of the CGE model



squatters generate demand for unskilled labor for deforestation, but only loggers generate demand for capital.

Costa Rica's total area has been divided into two types of land, cleared land and forested land. Cleared land is produced through deforestation. The production of cleared land depends on the definition of property rights as well as taxes on and subsidies for the factors of production and the profits in the forest and agriculture sectors.

Logs are assumed to be tradable. Therefore, the demand for forest land by the logging sector and the world market price determine the rate of deforestation. This demand is equal to the partial derivative of the logging cost function with respect to the user cost of logs plus the net export of logs.

The supply of cleared land is composed of the stock of cleared land plus deforestation by squatters. The demand for cleared land is the demand from the agriculture sector, which is set equal to the partial derivative of the agriculture sector cost function with respect to the user cost of cleared land.

The combination of production factors can be influenced by taxes and subsidies. Thus, a given user price is greater (smaller) than the corresponding supply price by a percentage tax (subsidy).

Technology, costs, and producer behavior

As shown in figure 11-2, the production factors have been aggregated into a composite input, Y. DLAND is combined with CAPITAL to yield an aggregate R, which in turn is combined with LOGS to generate M. The latter is combined with SLABOR to produce V, which is combined with ULABOR to yield the composite factor input, Y. This aggregation is accomplished through the use of constant elasticity of substitution (CES) production functions. The technology is specified to exhibit constant returns to scale. The relation between inputs and output is given by typical Leontief production functions for each sector.

Because the technology exhibits constant returns to scale, the marginal cost and the average cost of production in a given sector can be expressed as a linear function of prices, relevant input-output coefficients, and indirect tax rates.

Producers are assumed to maximize profits. The producer output prices, P_i, in the tradables producing sectors are given by the world market prices. Assuming perfect competition, this implies that pure profits are nonpositive, and output is non-negative and positive only if pure profits are equal to 0.

In the nontradables producing sectors, the sector-specific capital is endogenously adjusted so that price equals marginal cost.

Prices, domestic demand, foreign trade, and market clearing

For a good produced in the tradables producing sectors, the domestic producer price is equal to the world market price of the identical good, and in the nontradables producing sectors, the domestic user price is equal to the producer price times the tax rate.

The intermediate demand of a good is given by the technology assumptions. Domestic final demand is given by a linear expenditure system, derived from the consumers' utility maximization.

To equilibrate the market for a good, the net export for that good is defined as the difference between domestic supply and demand.

Deforestation sectors

In this model, two sectors are responsible for deforestation. They interact with the rest of the economy through their demands for capital and labor, by supplying forest products and clearing land for the rest of the economy, and through changes in the relative prices of factor inputs and sectoral outputs.

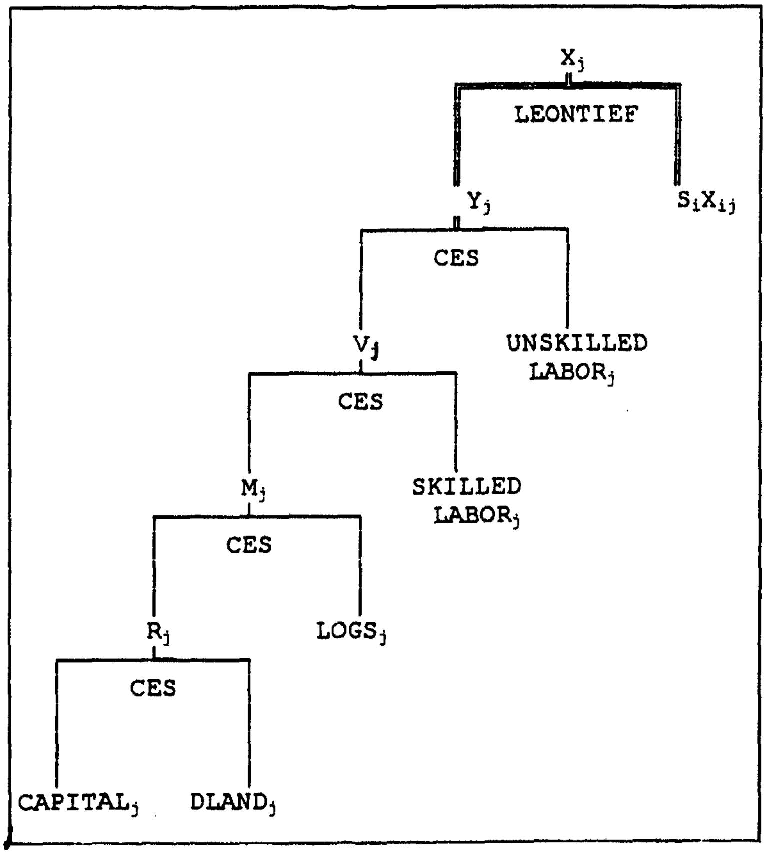
The logging sector. The logging sector is assumed to have capital-intensive technology (Repetto 1988). Further, the technology is assumed to exhibit decreasing returns to scale in order to reflect the diminishing amount of available forests, as well as the fact that much of the logging is done illegally. The production of logs is assumed to depend only on two factors of production: labor and capital. A log-linear production function is used. Because the technology used to model the diminishing yields in deforestation exhibits decreasing returns to scale, this implies that the returns to the production factors fall with increased deforestation. Deforestation for land and deforestation for logs are assumed to be independent of each other, and therefore the increased deforestation for logs does not affect the returns to deforestation for land, and vice versa. However, increased deforestation for logs implies decreasing yields in the logging sector, and increased deforestation for land implies diminishing returns in the squatting sector.

In the case of undefined property rights, loggers take only the private cost of deforestation into account. When property rights are well defined, the opportunity value of saving the forests is included in the loggers' cost function.

Squatters. The forested land cleared by squatters is seen as a common property, although there is no crowding effect because the stock of forested land is not included in the squatters' production function. The base case assumes undefined property rights. This section is inspired mainly by Johansson and Löfgren (1985).

The squatters have a production function for cleared land that increases monotonically with labor inputs. Their total revenue from clearing the land is the price paid for the cleared land. Part of the land cleared by squatters is sold to the agriculture sector, the rest is used for subsistence agriculture by the squatters themselves. However, because both activities occur, the

Figure 11-2 Aggregation of the factors of production



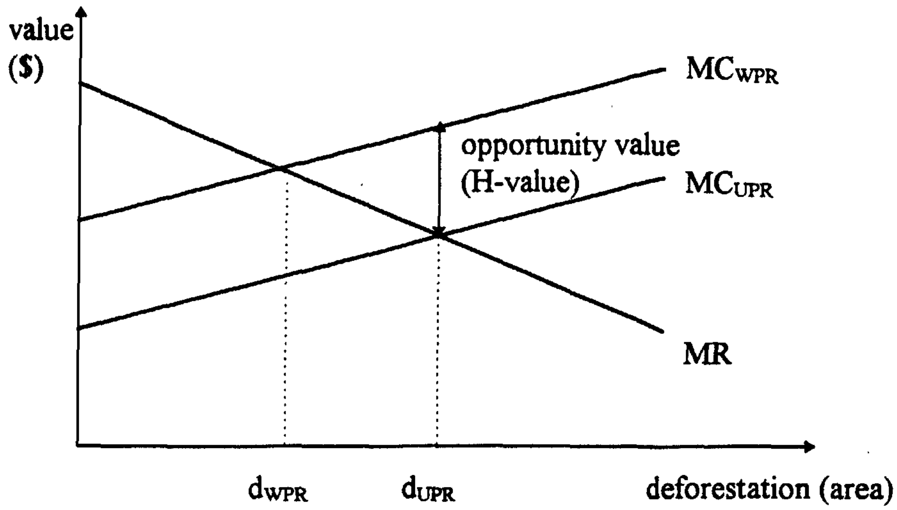
returns at the margin must be the same in each case. The squatters are assumed not to sell the timber from their deforestation. Other uses of the timber, such as for firewood, are assumed to be negligible.

The squatters' total private cost to clear the land depends only on the amount of labor needed in order to clear the land when property rights are undefined. This is the private cost, which does not include the future value of the forests and the cost of environmental damage. Therefore, the total social cost of deforestation is this private cost plus the future benefits from cleared forests that are forgone by clearing the land today. The future value of the forests is assumed to be greater than the value of the forests today.

The analysis of the definition of property rights can then be accomplished through the simulation of two regimes. In the case of undefined property rights, the present-day squatters do not take the future value of the forests into account.

When property rights are well defined, the squatters own their land and take the future value of the forests into account. The owners of forested land (that is, the "squat-

Figure 11-3 Definition of property rights



ters aware of the future") decide whether to preserve the forests or clear the land.

When property rights are undefined, no market for the forests is available to squatters. A simple partial model of land clearing by squatters (in which each squatter receives an equal share of the private profits) is used to show that land will be cleared until marginal cost equals marginal revenue. This result corresponds to maximization of private profit, given insecure land tenure.

When property rights are well defined, there is a market for the forests. The squatters take the future value of the forests into account, and they can choose to clear forested land or to preserve the forests. This is consistent with the condition for socially optimal forestry—that a tree should be harvested when the market value is equal to the shadow value (Hellsten 1988). This result corresponds to the optimization of net social benefits.

It can be deduced from the foregoing, as shown in figure 11-3, that more land is cleared when property rights are undefined (point dUPR) than when property rights are well defined (point dWPR). This is because the squatters' marginal cost of deforestation is lower when property rights are undefined (curve MCUPR) than when property rights are well defined (curve MCWPR), and the cost includes the future value of the forests. MR is the marginal revenue curve.

A more detailed analysis of the supply function indicates that when property rights are well defined, deforestation is increased by (a) a change of technology toward more efficient use of labor in the production of cleared land, (b) an increase of the time preference rate, and (c) an increase in the supply price of cleared land. Conversely, deforestation is reduced by increases in (a) the future value of the forests and (b) the price of labor.

When property rights are undefined, the clearing of land is not affected by the future value of forests and the rate of time preference. The effects of other variables are the same as in the earlier case.

The profit maximization condition for the squatters in the general equilibrium model includes a term reflecting the opportunity value of saving the forests for alternative uses or deforestation in a later time period. When property rights are undefined, the weight given to this term is 0, since future tenure of the forest is uncertain. When property rights are well defined, this term is included in the profit maximization.

Macroeconomic closure and measures of welfare

The current account is assumed to be constant, and the current account surplus is defined as the sum of net exports. There are three welfare measures in the model: the disposable income (which is implicitly determined from the current account), the green gross domestic product (GDP, which is determined as the sum of factor incomes plus a term that diminishes with increased deforestation to reflect the negative welfare effects of deforestation), and utility (which is determined from the consumer's utility function). Utility maximization results in a linear expenditure system for goods, based on a transformed Cobb-Douglas utility function.

Base case data, assumptions, and limitations of the model

The data used in this version of the model originate from Briceño (calculated from Solórzano and others 1991) and the national accounts (Banco Central de Costa Rica 1990). However, the sectors of production are not consistent between the two studies, and data were therefore adjusted in Raventós (1990). The input-output matrix in appendix 11-2, table 11A-1 was calculated from the disaggregated data used in Raventós (1990). The remaining differences were added to the net export column. Land use data are shown in appendix 11-2, table 11A-2. The economic rent to timber was calculated from Solórzano and others (1991). Deforestation in 1986 was assumed to equal average deforestation between 1973 and 1989. The value in 1986 prices was calculated using the increase in the consumer price index between January 1985 and December 1986. The rent to the production factor DLAND was subtracted from the rents to capital in the agricultural sector, and the labor used for land clearing by squatters was subtracted from the labor used in the same sector.

The labor and capital used for logging was subtracted from the payments to those factors in the forest sector. These data adjustments are shown in figure 11-4. Logging is assumed to be responsible for half of total deforestation, while land clearing by squatters is assumed to be responsible for the other half.

No estimates of elasticities of substitution between production factors are available. It is reasonable to assume that they are imperfect substitutes, and all substitution elasticities were therefore assumed to be less than 1. As a base case, the substitution elasticity between land and capital in the agriculture sector was set at 0.5. The substitution elasticity between the capital aggregate R and LOGS was assumed to be 0.8 in the forest sector, and the substitution elasticity between the aggregate M and LABOR was set at 0.8 in all producing sectors. Compared to other studies, such as Bergman (1990a, 1990b), these values appear reasonable. The remaining elasticities concern aggregates involving land and logs in sectors that cannot use those factors as inputs in production, and therefore the shares of those inputs in production always have to be 0. Those elasticities where set to 0, which is consistent with a fixed coefficient (Leontief) technology.

The parameters in the production functions for squatters and loggers are judgment-based estimates, assuming a labor-intensive technology for the squatters and a capital-intensive technology for the loggers.

In concluding this section, we note several limitations in the data and model formulation. First, because of the various data

Figure 11-4 Resource Flows and Data Adjustments

Sector	*Forest*	*Agriculture*	*Industry*	*Service*	*Infrastructure*	*Squatters*	*Loggers*	*Net exports*	*Domestic demand*	*Total demand*
Forest Agriculture Industry Service Infrastructure	Intermediate inputs					Deforestation sectors		Final demand		Total production demand
Squatters Loggers	+logf	+lsq								Deforestation demand
Labor Capital	-lgl -lgk	-lsq -lv				+lsq	+lgl +lgk			Factor income
Land		+lv								
Indirect taxes	Indirect taxes									Government revenue
Total	Output producing sectors					Deforestation		Total final demand		

Note: lsq = labor input in squatting; logf = logging; lgl = labor input in logging; lgk = capital input in logging; lv = land valu adjustments, the results of the simulations are mainly indicative and not necessarily precise quantitative measures. Second, because the model developed in this chapter is essentially static, the results are comparative snapshots of different policy experiments. Third, the approach developed here does not include some other possible linkages with deforestation. Migration and population growth are two causal factors that may be important (Harrison 1991), but they are not investigated. Furthermore, the model neither allows for re-afforestation nor includes erosion and other external effects of deforestation. The economic valuation of such environmental effects and their incorporation into conventional economic analysis would be a formidable task (see, for example, Munasinghe 1993a).

Results

Simulations of different policy experiments and the definition of property rights generated some results that are different from what could be expected from the partial equilibrium framework discussed earlier. This is due to substitution effects in the producing sectors. Table 11-2shows the relative factor intensities in the base case.

The situation of today with undefined property rights was taken as a base case. As a first step, property rights were defined and the opportunity value of the forests (the *H*-value) was set 28 percent higher than the value derived from deforestation (Solórzano and others 1991). The discount rate was set at 10 percent. The results are displayed in table 11-3.

Table 11-2 Initial capital intensities

(percentages)

Input	*Forest*	*Agriculture*	*Industry*
Land	0.00	14.81	0.00
Capital	31.93	14.68	11.73
Unskilled labor	25.63	19.41	8.25
Skilled labor	0.43	0.32	5.41

Table 11-3 Effect of future valuation on value of production (billions of colones)

	Property rights			
		Defined (H-value)[a]		
Item	*Undefined*	*0.4792*	*0.2792*	*0.0792*
Deforestation				
Logging	0.020	0.000	0.002	0.010
Squatting	0.020	0.000	0.000	0.000
Total	0.040	0.000	0.002	0.011
Production				
Forestry	0.552	0.713	0.711	0.691
Agriculture	13.984	13.876	13.876	13.879
Industry	18.477	18.416	18.417	18.424
Utility	0.232	0.232	0.232	0.232
Green GDP	31.962	31.972	31.971	31.971
Disposable income	37.681	37.679	37.679	37.679

a. *H*-value is the future value per unit of forest.
Source: Authors' calculations.

Table 11-4 The effects of taxes and subsidies on production factors
(billions of colones)

Item	Base case	Logs: With tax	Logs: With subsidy	Land: With tax	Land: With subsidy	Unskilled labor: With tax	Unskilled labor: With subsidy	Capital: With tax	Capital: With subsidy
Deforestation									
Logging	0.020	0.000	0.018	0.020	0.019	0.029	0.013	0.036	0.011
Squatting	0.020	0.044	0.004	0.000	0.255	0.210	0.000	0.020	0.020
Total	0.040	0.044	0.023	0.020	0.273	0.239	0.013	0.056	0.031
Production									
Forestry	0.552	0.000	1.562	0.672	0.000	0.000	0.689	0.515	0.574
Agriculture	13.984	14.204	13.748	13.877	15.122	14.922	13.877	13.987	13.983
Industry	18.477	19.248	17.017	18.430	17.656	17.946	18.424	18.487	18.471
Utility	0.232	0.243	0.214	0.231	0.226	0.229	0.232	0.232	0.233
Green GDP	31.962	32.017	31.848	31.960	31.757	31.797	31.965	31.943	31.958
Disposable income	37.681	37.748	37.561	37.678	37.592	37.620	37.679	37.680	37.682

Source: Authors' calculations.

A comparison of the first and second columns shows that the definition of property rights results in a dramatic decrease in deforestation and an increase in the net import of logs (not shown in the table). Activity in the forest sector increases significantly because logs can be imported at a constant world market price. The increase in the price of capital is offset by decreases in the price for labor. Deforestation by squatters ceases, and activity in the agricultural sector declines, but to a relatively small extent, because land (which is relatively less expensive than capital after the definition of property rights) and labor can be substituted for capital in the sector. The welfare measures remain constant because consumption of different goods is unchanged.

Sensitivity analysis (remaining columns in table 11-3) shows that even a relatively small opportunity value of forests (for example, $H = 0.0792$) decreases deforestation dramatically. However, for deforestation to cease completely, a high value ($H = 0.4792$) is required. Both the opportunity value of forests and the interest rate are exogenous to the model. Varying the interest rate while keeping the opportunity value fixed shows that high interest rates promote deforestation, and vice versa. The results of varying the interest rate may be deduced from table 11-3, because a decrease in the interest rate is equivalent to an increase in the opportunity value, and vice versa. This result is shown in Figure 11-5.

Next, the effects of taxes on logs, land, unskilled labor, and capital were investigated, as summarized in table 11-4. A 10 percent tax increase on logs generated predictable results, with no deforestation from loggers and no production in the forest sector. Resources were shifted to the agricultural sector, with an increase in deforestation for land and an increase in total deforestation. The increase in total deforestation can be explained by the lower price of unskilled labor, resulting from the discontinued production in the forest sector. The tax increase actually results in a higher level of utility, as well as an increase in green GDP.

Taxes and subsidies on land generate expected results, with a corresponding change in deforestation by squatters and roughly constant deforestation by loggers. Both the tax and the subsidy are distor-tionary and reduce utility as well as income and GDP. When a tax on land is imposed, land becomes relatively expensive compared to logs, and resources are shifted from the agricultural sector to the forest sector, with a corresponding change in production. It is worth noting that the land subsidy dramatically increases deforestation for land, a fact that was empirically observed in Costa Rica earlier this century.

A 10 percent tax increase on unskilled labor adversely affects the forest sector and the industry sector, but logging continues and logs are exported. After the tax increase, the price of land is low relative to other production factors, and resources are shifted toward the agricultural sector. The price of unskilled labor in the deforestation sectors is actually reduced, because those sectors are considered to be "informal" in the sense that their activities are to a large extent illegal and remain unaffected by government tax policies. Resources are shifted to the agricultural sector, with a large increase in land clearing by squatters as a result. These results also hold for the experiments with capital tax policies, although the magnitude of the changes is smaller.

Substitution effects prove to be important for policy experiments involving tax changes on goods produced in tradables sectors, as summarized in table 11-5.

The effects of tax changes on goods from the forest sector generate small economy-wide effects, because this sector is small compared to the others. The industrial sector (which uses forest products relatively intensively as an intermediate input) gains from the tax reduction and grows, while the forest sector itself suffers. The effects are reversed for a doubling of the tax on forest products. Deforestation remains largely unaffected in both cases.

When the tax on agricultural products is reduced to half, the agricultural sector actually decreases, as does the forest sector. This is due to an elevated price of unskilled labor, which both sectors use relatively intensively. The industrial sector benefits because of its extensive use of agricultural products as intermediate inputs and because capital becomes the relatively least expensive production factor. Deforestation for logs remains constant, while deforestation for land is somewhat reduced. Utility, income, and green GDP measures are reduced. A double tax on agricultural products generates the opposite effects. A tax on products from the industrial sector generates the same effects as a tax on agricultural products, although the magnitude of the changes is larger.

A dynamic version of this model, which captures the intertemporal optimization behavior in the economy, is described in Persson (1994). This model is a two-period model, which allows consumers and producers to take the future effects of the policy changes into account in their decisions in the first period. In the dynamic model, the opportunity value of forest conservation (the H-value) is endogenous and influenced by relative prices and the size of forests available for deforestation. Further, capital investments are endogenous in the dynamic model, as is the domestic interest rate.

In the dynamic model, the results from the static model hold. Well defined property rights result in less deforestation, as does a lower tax on capital. The qualitative results from the dynamic model thus coincide with the results of the static model, confirming the robustness of the results presented here.

Conclusions

The results of the CGE study support the more conventional partial equilibrium approach that establishing property rights tends to decrease deforestation. The reason is that such rights allow forest users to capture the future benefits of reduced logging damage today. Initially, this potentially avoidable loss is presumed to be 28 percent of the value of the residual stand, based on a recent environmental accounting study (Solórzano and others 1991). Using an interest

Table 11-5 The Effects of changes in taxes on final products (billions of colones)

		Sector (change relative to original tax rate)					
		Forestry		*Agriculture*		*Industry*	
Item	*Base case*	*Half*	*Double*	*Half*	*Double*	*Half*	*Double*
Deforestation							
Logging	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Squatting	0.020	0.020	0.020	0.019	0.022	0.018	0.025
Total	0.040	0.040	0.040	0.039	0.042	0.038	0.045
Production							
Forestry	0.552	0.528	0.609	0.405	0.902	0.160	1.363
Agriculture	13.984	13.984	13.985	13.258	15.706	13.964	14.030
Industry	18.477	18.503	18.418	19.243	16.663	18.268	18.909
Utility	0.232	0.229	0.240	0.135	0.459	0.064	0.572
Green GDP	31.962	31.941	31.980	31.589	32.815	31.324	33.253
Disposable income	37.681	37.669	37.709	37.317	38.544	37.051	38.984

Source: Authors' calculations.

rate of 10 percent, the simulation indicates that deforestation is dramatically reduced to 5 percent of the base level as both loggers and squatters internalize the losses associated with deforestation and reduce the corresponding activities. Significant reductions in deforestation occur even when the estimate of logging damage is substantially reduced. The CGE results concerning the effects of discount rate changes also parallel the predictions of partial equilibrium models—higher interest rates promote deforestation, while lower interest rates contribute to conservation.

Beyond confirming the direct results of partial equilibrium analyses, the CGE approach also makes an important contribution by clearly identifying the indirect effects arising from intersectoral linkages. This impact must be combined with the direct effects attributable to policies that are specific to the forest sector to determine the total impact. For example, partial equilibrium analysis predicts that stumpage price increases act directly to reduce logging, yet the model shows that while deforestation from logging indeed declines, total deforestation nevertheless increases. This phenomenon arises from indirect linkages captured by the general equilibrium analysis. The contraction of the logging and forest industry sectors causes a shift of resources toward agriculture, and as agriculture expands, deforestation increases.

The importance of such indirect effects is also demonstrated in the analysis of economywide policy changes, such as an increase in the wage rate. Because of intersectoral resource flows, the general equilibrium model captures effects of changes in wages that are different from partial equilibrium results. If the wage of unskilled labor were increased (for example, due to minimum wage legislation), the model predicts that deforestation could worsen instead of decline. Although logging declines due to increased direct costs of higher wages, this is more than offset by the indirect effect of intersectoral flows because the industrial sector (where minimum wage legislation is more binding) is much more adversely affected by the higher labor costs. Labor and capital thus tend to flow to agriculture, leading to the conversion of even more forest land for farming.

Finally, both these last two examples underline the importance of pursuing sectoral reforms in the context of growth. Without alternative employment opportunities, reducing logging activities tends to direct labor and capital resources toward agriculture, industry, and other sectors. Expansion of some of these sectors may lead to a second round of effects on forestry, which could ultimately result in more severe deforestation. A dynamic CGE model, in which the value of forest conservation, capital accumulation, and the domestic interest rate are endogenized, gives essentially the same results as the static CGE model presented here.

Appendix 11-1. Summary of CGE model structure

Factor market equilibrium and the stock of forested land

The supplies of labor and capital are assumed to be exogenously given. According to Shephard's lemma, the demand for a production factor within a sector is the partial derivative of the cost function with respect to the price of the same production factor. The market equilibrium conditions for capital, unskilled labor, and skilled labor, respectively, can be written:

$$K = \sum_{j\in T,N} \frac{\partial C_j}{\partial P_K^U} + k^{\log} \tag{11A-1}$$

where $P_K{}^U$ is the user price of capital and $k^{\log}$ is the capital used in deforestation by loggers, and

$$U = \sum_{j\in T,N} \frac{\partial C_j}{\partial P_U^U} + l^{sq} + l^{\log} \tag{11A-2}$$

$$L = \sum_{j\in T,N} \frac{\partial C_j}{\partial P_L^U} + l^{sq} + l^{\log}$$

where P_U^U is the user price of unskilled labor, l^{sq} and l^{log} are the labor used in deforestation by squatters and loggers, respectively, and P_L^U is the user price of skilled labor. Equations 9A-1 and 9A-2 state that the supplies of labor and capital must equal the demand from the producing sectors plus the amount used for deforestation by squatters and loggers.

Costa Rica's total area is divided into two types of land, cleared land and forested land. Cleared land is produced through deforestation. The production of cleared land will depend on the definition of property rights as well as taxes and subsidies on the factors of production and the profits in the forest and agriculture sectors.

It is assumed that there is a world market for logs. The market equilibrium condition for logs can then be written:

$$(11A\text{-}3) \quad \alpha d^{FOREST} = \frac{\partial C_{FOREST}}{\partial P_F^U} - f^{nexp}$$

where d^{FOREST} is deforestation from the logging sector, P_F^U is the user price of logs, f^{nexp} is the net export of logs, and _ is a fixed coefficient reflecting the amount of timber extracted per unit of deforested land. The production of logs is further discussed in the section on the logging sector.

The value of the deforestation is calculated here from the loss of standing volume in Solórzano and others (1991). The coefficient * was assumed to be equal to 1. There is no general agreement among biologists regarding the amount of biodiversity loss resulting from highgrading. If the value of deforestation is defined to represent biodiversity loss as well as loss of standing volume, and highgrading causes high losses of biodiversity, this modified coefficient would still be close to 1. An alternative interpretation, consistent with the view that the biodiversity loss is proportional to the number of trees extracted, is that squatters and loggers each remove half of the timber following the process described in Carriére (1991a, 1991b). In this case also, the modified coefficient would be nearly equal to 1. Thus the model is valid for either of the last two interpretations, but the actual value of the economic loss would have to be adjusted upward. Due to lack of data regarding the value of biodiversity, the first approach of valuing only the timber was selected, since it is a conservative estimate. However, the true value of the loss of forests is higher.

The supply of cleared land is composed of the stock of cleared land, DL^*, plus deforestation by squatters, d^o. The production of cleared land by squatters is further discussed in the section on squatters.

The demand for cleared land is the demand from the agriculture sector. The market equilibrium condition can then be written:

$$(11A\text{-}4) \quad \frac{\partial C_{AGRICULTURE}}{\partial P_{DL}^U} - DL^* - d^o = 0.$$

The combination of production factors can be influenced by taxes and subsidies. The user price, P_j^U, will exceed the supply price, P_j^S, by a percentage tax, T_j:

$$(11A\text{-}5) \quad P_j^U = P_j^S(1+T_j);$$

$$j = DLAND\ (DL),\ LABOR\ (UL,\ SL),\ CAPITAL\ (K),$$

$$P_F^U = P_F^{WM}(1+T_F);\ LOGS$$

In the case of logs, the supply price is determined by the world market price.

Technology, costs, and producer behavior

The production factors have been aggregated into a composite input, Y, using constant elasticity of substitution (CES) functions. The technology is specified to exhibit constant returns to scale. The relation between inputs and output is given by sectoral Leontief production functions of the following type:

(11A-6)
$$X_j = \min\left[\frac{Y_j}{A_j}, \frac{X_{ij}}{a_{ij}}\right] \quad i,j \in T,N$$

where X_j is the gross output in sector j, Y_j is a composite input of production factors in sector j, X_{ij} is input of output from sector i in sector j, and A_j and a_{ij} are Leontief input-output coefficients. Because the technology exhibits constant returns to scale, the marginal cost and the average cost of production in sector j can be written as

(11A-7)
$$C_j = P_{Yj} A_j + \sum_i P_i^D a_{ij} + t_j; \quad i,j \in T,N$$

where C_j is the marginal and average cost in sector j, P_{Yj} is the producer price of the composite input of production factors, P_{iD} is the domestic price of sector i output, A_j is the use of production factors per sector j output, a_{ij} is the use of sector i input per sector j output, and t_j is indirect tax per unit of sector j output.

Producers are assumed to maximize profits. The producer output prices, P_i, in the tradables producing sectors are given by the world market prices. Assuming perfect competition, this implies that pure profits are non-positive and that output is non-negative and positive only if pure profits are equal to 0:

(11A-8)
$$P_i - C_i \le 0; \quad i \in T$$
$$(P_i - C_i) X_i = 0; \quad i \in T$$
$$X_i \ge 0; \quad i \in T$$

In the nontradables producing sectors, the sector-specific capital is endogenously adjusted so that price equals marginal cost:

(11A-9)
$$P_i = C_i; \quad i \in N$$

Prices, domestic demand, foreign trade, and market clearing

For goods produced in the tradables producing sectors, the domestic producer price is equal to the world market price of identical goods, and in the nontradables producing sectors the domestic user price is equal to the producer price times the tax rate:

(11A-10)
$$P_i^D = (1+\sigma_i) P_i^W e = (1+\sigma_i) P_i; \quad i \in T$$

(11A-11)
$$P_i^D = (1+\sigma_i) P_i; \quad i \in N$$

where P_i^D is the domestic user price of goods produced in sector i, P_i^W is the world market price of good i, P_i is the producer price of good i, e is the exchange rate, and s_i is the ad valorem tax rate on good i.

The intermediate demand of good i is given by the technology assumptions. Domestic final demand (D) is given by utility maximization (equation 9A-35). The net export (Z) is determined as the difference between domestic supply and demand. The market equilibrium conditions then become

(11A-12)
$$X_i = \sum_{j \in T,N} a_{ij} X_j + D_i + Z_i; \quad i \in T$$

(11A-13)
$$X_i = \sum_{j \in T,N} a_{ij} X_j + D_i; \quad i \in N$$

Deforestation sectors

In this model, two sectors are responsible for deforestation. These are discussed below.

The logging sector

The logging sector is assumed to have a capital-intensive technology (Repetto 1988). Further, the technology is assumed to exhibit decreasing returns to scale in order to reflect the diminishing amount of available forests as well as the fact that much of the logging is done illegally. The production of logs is assumed to depend only on two factors of production: unskilled labor and capital. The log-linear production function is

(11A-14)
$$d^{FOREST} = (k^{\log})^{\alpha} (l^{\log})^{\beta}, \quad \alpha + \beta < 1$$

Undefined property rights. From profit maximization, we have that the demands for capital and unskilled labor are

(11A-15)

$$(k^{\log}) = \left(\frac{P_K}{\alpha P_F (l^{\log})^{\beta}}\right)^{\frac{1}{\alpha - 1}}$$

$$(l^{\log}) = \left(\frac{P_U}{\beta P_F (k^{\log})^{\alpha}}\right)^{\frac{1}{\beta - 1}}$$

Hence the production function for logs can be written as

(11A-16)

$$(d^{\log}) = \left(\frac{P_K}{\alpha P_F (l^{\log})^{\beta}}\right)^{\frac{\alpha}{\alpha - 1}} \left(\frac{P_U}{\beta P_F (k^{\log})^{\alpha}}\right)^{\frac{\beta}{\beta - 1}}$$

Well defined property rights. When property rights are well defined, the logging companies take the opportunity value of the forests into account. The opportunity value is represented by a function $H(d)$ and is exogenous to the model. Hence, in the case of well defined property rights, the logging sector's demand for unskilled labor and capital, respectively, are

(11A-17)

$$(l^{\log}) = \left(\frac{P_U^U + \dfrac{\partial H(d)}{\partial (l^{\log})}}{\beta P_F (k^{\log})^{\alpha}}\right)^{\frac{1}{\beta - 1}}$$

$$(k^{\log}) = \left(\frac{P_U^U + \dfrac{\partial H(d)}{\partial (l^{\log})}}{\alpha P_F (l^{\log})^{\beta}}\right)^{\frac{1}{\alpha - 1}}$$

Squatters

The forested land cleared by squatters is seen as a common property, although there is no crowding effect because the stock of forested land is not included in the squatters' production function. The base case assumes undefined property rights, although property rights are not undefined in the traditional sense. Instead, it can be seen that a form of short-term property rights is created; because of the short time horizon, the opportunity value of keeping the forests is not taken into account.

The squatters have a monotonically decreasing production function for cleared land with unskilled as the only factor of production:

(11A-18) $\quad d^o = d(l^{sq}) = l^{sq^{\gamma}}; \quad \gamma < 1.$

with

(11A-19)
$$d(0) = 0,$$
$$d_l(l^{sq}) > 0,$$
$$d_{ll}(l^{sq}) < 0,$$

and

(11A-20) $$\lim_{n \to \infty} d(l^{sq}) = B,$$

where n is the number of squatters, l^{sq} is the labor used in the clearing of the land, and B is the total amount of land available for deforestation.

The squatters' total revenue from clearing the land is the price paid for the cleared land:

(11A-21) $\quad I^s(d^o) = P_{DL}^S d^o$

where P_{DL}^S is the supply price of cleared land. Part of the land cleared by squatters is sold to the agriculture sector, and part of the cleared land is used for subsistence agriculture by the squatters themselves. However, because both occur, the revenue must be the same in both cases. The squatters are assumed not to sell the timber from their deforestation. Other uses of the timber, such as for firewood, are assumed to be negligible and are therefore set to 0.

The squatters' total private cost for clearing the land will depend only on the amount of labor needed in order to clear the land when property rights are undefined,

(11A-22) $$C^s(d^o) = P_L^{sq} d^{-1}(d^o)$$

where P_L^{sq} is the price of labor in squatting. This is the private cost, and it does not include the future value of the forests and the cost of environmental damage. The total social cost of deforestation includes the future value of the cleared forests forgone by clearing the land today. The future value of the forests is assumed to be greater than the value of the forests today:

(11A-23) $$\frac{H(F)}{1+i} > 1.$$

Undefined property rights. When property rights are not defined, the land is seen as a common property. No market for the forests is available to squatters. The production of cleared land by squatter i is

(11A-24) $$d_i^o = \frac{1}{N} d(l^{sq})$$

where N is the total number of squatters and the squatters' total production of cleared land is

(11A-25) $$d^o = \sum_{i=1}^{N} d_i^o$$

The total private profit from clearing the land is

(11A-26) $$g^s(d^o) = I^s(d^o) - C^s(d^o)$$

of which each squatter receives an equal share:

(11A-27) $$g_i^s(d^o) = \frac{1}{N} g^s(d^o)$$

However, for the sector as a whole, land will be cleared until marginal cost equals marginal revenue. From the profit function, we have that the squatters demand for unskilled labor is

(11A-28) $$l^{sq}(P_{DL}, P_U) = \left(\frac{P_U}{\gamma P_{DL}}\right)^{\frac{1}{\gamma - 1}}$$

and the supply of cleared land is

(11A-29) $$d^o = \left(\frac{P_U}{\gamma P_{DL}}\right)^{\frac{\gamma}{\gamma - 1}}$$

Well defined property rights. When property rights are well defined, there is a market for the forests. The squatters take the future value of the forests into account, and they can choose to clear forested land or to preserve the forests. This is consistent with the condition for socially optimal forestry that a tree should be harvested when the market value is equal to the shadow value (Hellsten 1988). Assuming that all squatters are identical and that every squatter owns 1 / N of the land that previously was available for squatting, the total private profits from clearing the forested land is now (Johansson and Löfgren 1985):

(11A-30)
$$g^{fs}(d^o) = P_{DL}^s d^o - C^s(d^o) - \frac{H(d^o)}{1+i}$$

Deforestation will occur until marginal cost equals marginal revenue, and from the profit function we have that

(11A-31)
$$l^{sq} = \left(\frac{P^U{}_U + \frac{\partial(H(l^{sq^\gamma})/(1+i))}{\partial l^{sq}}}{g P_{DL}}\right)^{\frac{1}{\gamma - 1}}$$

(11A-32)
$$d^o = \left(\frac{P^U{}_U + \frac{\partial(H(l^{sq^\gamma})/(1-i))}{\partial l^{sq}}}{\gamma P_{DL}}\right)^{\frac{\gamma}{\gamma - 1}}$$

This result is equal to the result of the social optimization problem.

Macroeconomic closure

The current account is assumed to be constant. This implies that

(11A-33) $\sum_{i \epsilon T,N} P_i Z_i = S$

where S is the current account surplus. Equation 9A-33 indirectly determines the disposable income (I).

The gross national product is determined as the sum of factor incomes plus a term reflecting the value of diminished deforestation:

(11A-34)

$$GNP = P_K^U K + P_L^U L + P_U^U U + P_{DL}^U DL^* + \sum_{j \epsilon T,N} \sigma_j X_j - \Delta(d^o + d^{\log})H(1).$$

The model is solved by maximizing consumer utility subject to a budget constraint:

(11A-35) Max $U = \prod_i D_i^{b_i}; \sum_i b_i = 1; i \in N,T$

$$s.t.\ I - \sum_i P_i\ D_i = 0$$

Appendix 11-2 Data for Costa Rica

Table 11A-1 Base case data for the CGE Model, Costa Rica, 1986

(billions of colones)

Sector and item	*Forestry*	*Agriculture*	*Industry*	*Infrastructure*	*Services*	*Consumption*	*Net exports*	*Total*
Sector								
Forestry	0.003	0.022	0.391	0.002	0.000	0.124	0.011	0.552
Agriculture	0.004	4.033	2.488	0.000	0.000	3.535	3.924	13.984
Industry	0.137	1.405	7.390	3.418	1.343	14.426	−9.643	18.477
Infrastructure	0.004	0.293	0.826	0.647	0.684	8.366	0.000	10.821
Services	0.038	0.602	1.546	1.487	2.160	11.230	0.000	17.062
Land	0.000	2.070	0.000	0.000	0.000	0.000	0.000	2.070
Logs	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.022
Capital	0.176	2.052	2.168	1.633	5.256	0.000	0.000	11.285
Unskilled labor	0.141	2.714	1.525	1.754	1.439	0.000	0.000	7.573
Skilled labor	0.002	0.045	0.999	1.299	4.904	0.000	0.000	7.250
Indirect tax	0.025	0.747	1.145	0.580	1.276	0.000	0.000	3.773
Total	0.552	13.984	18.477	10.821	17.062	37.681	−5.708	92.870

Note: The subsectors of the input-output table are aggregated into the five production sectors as follows: forestry (forestry and fishing); agriculture (bananas, unprocessed coffee, sugar cane, cacao, basic grains, cotton, tobacco, livestock, other agricultural products, coffee processing, grains milling, sugar refining); industry (meat and milk, fish tinning, edible oils, bakeries, other manufactured goods, drink, tobacco products, textiles and clothing, leather and shoes, timber and furniture, paper and printing, chemical products, oil refining, tire products, plastic and rubber, glass and ceramic, construction materials, metal products, electric products, transport equipment, other manufacturing); infrastructure (construction, transport, electricity, gas and water); and services (banking and finance, commerce, ownership of dwellings, general government). The GNP is 26.148 billions of colones.

Source: Authors' calculations from Raventós (1990) using Briceño (1986), Solórzano and others (1991), and Banco Central de Costa Rica (1990). The adjustments have been calculated from Solórzano and others (1991).

Table 11A-2 Land Use Data, Costa Rica, Selected Years

	1963		*1973*		*1986*	
Land use	*Area (square kilometers)*	*Percentage of total land*	*Area (square kilometers)*	*Percentage of total land*	*Area (square kilometers)*	*Percentage of total land*
Agriculture	1,544.796	30.09	2,048.512	39.90	2,944.616	57.36
Primary forest	3,154.280	61.44	2,666.005	51.93	1,760.622	34.30
Secondary forest	299.011	5.82	283.571	5.52	292.850	5.70
Other	135.593	2.64	135.593	2.64	135.593	2.64
Total	5,133.680	100.00	5,133.681	100.00	5,133.681	100.00

Note: Percentages may not add up to 100 because of rounding.
Source: Authors' calculations based on data from Solórzano and others (1991).

Notes

1. A billion is 1,000 million. All dollars are U.S. dollars unless otherwise noted.
2. The subsectors of the input-output table are aggregated into the five production sectors as follows:

   • forest (forestry and fishing);

   • agriculture (bananas, unprocessed coffee, sugarcane, cacao, basic grains, cotton, tobacco, livestock, other agricultural products, coffee processing, grains milling, and sugar refining);

   • industries (meat and milk, fish tinning, edible oils, bakeries, other manufactured goods, drinks, tobacco products, textiles and clothing, leather and shoes, timber and furniture, paper and printing, chemical products, oil refining, tire products, plastic and rubber, glass and ceramic, construction materials, metal products, electric products, transport equipment, and other manufacturing);

   • infrastructure (construction, transport, electricity, gas, and water); and

   • services (banking and finance, commerce, ownership of dwellings, and general government).

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