For Staff Use Only

A World Grains and Soybeans Model

Donald O. Mitchell

Division Working Paper No. 1985-7
December 1985

Commodity Studies and Projections Division
Economic Analysis and Projections Department
Economics and Research Staff
The World Bank

Division Working Papers report on work in progress and are circulated for Bank staff use to stimulate discussion and comment.

A World Grains and Soybeans Model

December 1985

Prepared by: Donald O. Mitchell
Commodity Studies and Projections Division
Economic Analysis and Projections Department
Economics and Research Staff
The World Bank

PREFACE

The Commodities Studies and Projections Division has recently completed the construction of global models of grains (wheat, rice and coarse grains) and soybeans markets under the supervision of Mr. Don Mitchell. This paper describes in broad terms the specification used to model these markets. As the specification is the same for each of the commodities with linkages through prices and area harvested, the models may be run separately or as one model.

The countries involved in a major way in the production, consumption and trade of the grains and soybeans appear separately in the models. It is possible to carry out simulations featuring changes in policies within any of these countries to observe the impact on the country itself or on the global markets. The models, therefore, can be of assistance to Bank staff evaluating changes in agricultural policies in any of these countries or groups of countries. The Division will be pleased to cooperate in utilizing the models for such studies.

Ronald C. Duncan, Chief
Commodities Studies and Projections Division
Economics and Research Staff

TABLE OF CONTENTS

I. INTRODUCTION 1/

1. This paper describes the recently-completed world grains and soybean model currently used by the Commodity Studies and Projections Division. The model is a non-spatial, partial-equilibrium, net-trade model. It is global in scope with 15 countries modeled individually and the remaining countries grouped into nine regions.

2. The commodities included in the model are wheat, rice, coarse grains (maize, oats, barley, sorghum, rye, millet, and mixed grains), soybeans, soymeal and soyoil. Individual models have been estimated for each commodity and country or region with cross linkages between commodities. Soybeans are modeled in terms of beans on the production side but in terms of oil and meal in the consumption and trade components.

3. Production for each country or region is determined as the product of separately-estimated harvested-area and yield equations. Harvested area is determined by a two-stage process wherein total area harvested is determined first and then allocated among competing crops on the basis of lagged per acre revenues. Yields are estimated as a function of lagged crop prices, fertilizer prices, the proportion of area planted to high-yielding varieties and a linear trend.

1/ The estimation of the soybean model was carried out by Mr. T.Y. Pee. Mr. Alan Bowers gave very able research assistance in all aspects of construction of the grains and soybeans model.

4. Per capita imports of each commodity are estimated directly for importing countries as a function of population, income, domestic supply and prices. Ending stocks are estimated as a share of consumption and prices. Total consumption is obtained as an identity. Net exports are estimated for exporting countries as a function of the level of each commodity available for export and world prices. Consumption in the exporting countries is estimated as a function of population, income and prices.

5. The model is solved simultaneously for the level of world prices which equate net imports and net exports. A trade hierarchy is assumed which allows small exporters to export as much as they desire while forcing the United States to be the residual supplier.

6. The primary objective of the model is to provide a basis for medium term (one to ten years) annual projections of world prices, and projections of trade, production, consumption and ending stocks for each country or region. A secondary objective is to provide a flexible global framework within which more detailed policy analysis models can be built and simulated.

II. MODEL DESCRIPTION

7. The general structure of the global model is shown in Figure 1. Each country model takes the price from the world linkage and returns the level of net trade. This structure allows great flexibility in the design and level of detail in the country models. When a particular policy simulation requires greater country detail than is provided by the standard model, a more detailed model is built and inserted in place of the standard model.

8. The variables used in the model must satisfy several criteria. First, and most importantly, the variables must be appropriate for capturing the economic relationships within the commodity markets of the countries and regions of the world market. Second, since the variables are to be used in an econometric model, a time series extending over approximately 20 years is desired. Third, the desired output of the model must be satisfied by the variables selected. Finally, forecasts of the exogenous variables used in the model should be available for the relevant future period.

9. Table 1 contains the list of exogenous and endogenous variables used in the model, along with their sources, definitions and availability of forecasts and updates. One difficulty with commodity data is the distinction between a calendar year and a crop year. Some agricultural data, such as stocks, are only available on a crop year basis. Other macro economic data, such as income, are available only for a calendar year. Regardless of the year definition selected, some incompatibilities will be encountered. If a calendar year is selected, consumption and trade for a single harvest fall in two years. If a crop year is selected, the macro economic definitions do not correspond. A crop-year basis is used in this model in order to focus on the agricultural aspects of the model.

FIGURE 1: WORLD GRAIN AND SOYBEANS MODEL

Country/Region j	World Linkage
Commodity i	Commodity j
Year t	Year t

Ending Stocks $_{i,j,t-1}$

↓

\+

↓

Production $_{i,j,t}$

↓

=

↓

Domestic Supply $_{i,j,t}$ ← World Price $_{i,t}$

↓

\+

↓

Net Trade $_{i,j,t}$ → $\sum_{i=1}^{n}$ Net Trade $_{i,t} = 0$

↓

\-

↓

Consumption $_{i,j,t}$

↓

=

↓

Ending Stocks $_{i,j,t}$

TABLE 1: AGRICULTURAL MODEL VARIABLE LIST /A

Variable	Source	Definition	Years	Forecast	Frequency and Source of Updates
EXOGENOUS VARIABLES					
Population	WB, UN	Million People Calendar Year	1960-83	2000	Annually, WB, UN
Income -- GDP	WB, IFS	Billion Local Currency Calendar Year	1960-83	1995	Quarterly, WB, OECD, WEFA
EXCHANGE RATE TO $	WB, IFS	Local Currency/US $ Calendar Year	1960-83	1995	Quarterly, WB, WEFA
Consumer Price Index	WB, IFS	Index, 1975=100 Calendar Year	1960-83	1995	Quarterly, WB, WEFA
ENDOGENOUS VARIABLES					
World Crop Prices	USDA	$/MT, f.o.b., gulf Simple Monthly Average Crop Year	1960-84		Monthly, USDA
Country Crop Price	As available				
Retail	FAO, WB, USDA				
Wholesale	FAO, WB, USDA				
Production	USDA	Thousand Metric Tons Crop Year	1960-83		Monthly, FAS, USDA, World Grain Situation/Outlook
Harvested Area	"	Thousand Hectares Crop Year	1960-83		Semi Annually, Sept & March, FAS, USDA Reference Tables on Supply-Utilization
Crop Yields	"	Tons Per Hectare	1960-83		"
Consumption Food Use Feed Use Seed Use	"	Thousand Metric Tons Crop Year	1960-83		"
Net Trade	"	Thousand Metric Tons Crop Year	1960-83		Semi-Annually, Sept & March, FAS, USDA Reference Tables on Supply Utilization Monthly, Calendar Year Basis, FAS, USDA World Grain Situation/Outlook
Beginning Stocks	"	Thousand Metric Tons Crop Year	1960-83		Semi-Annually, Sept & March, FAS, USDA Reference Tables On Supply-Utilization

/A Data sources are WB = World Bank; FAO = Food and Agriculture Organization; IFS = International Financial Statistics published by the International Monetary Fund; USDA = U.S. Department of Agriculture; WEFA = Wharton Econometric Forecasting Service; FAS = Foreign Agriculture Service of USDA; OECD = Organization for Economic Cooperation and Development.

10. Every model necessarily involves compromise and simplifications of the real world. This model does not consider a number of topics which are important, but which have not been modeled at this stage. Quality differences within each product are not considered; each commodity is treated as homogeneous and having a single world price. Trade flows between countries are also ignored; trade is assumed to take place in a world market yielding only net trade figures. Resource use for production is also largely ignored with the exception of land and fertilizer. Transportation costs are also not considered at this stage.

11. Given the size of the model and the important variables which are not included, it is apparent that the model will provide a framework for research not a rigid forecasting model. The model is constructed so that individual variables, such as yields, can be analyzed and modified by expert opinion. In this way the important variables which cannot be explicitly included, can be reflected in model variables. This approach is consistent with the Commodity Studies and Projections Division's approach to forecasting which uses opinion from country experts in the preparation of forecasts.

12. The model has been estimated primarily with ordinary least squares, using annual data from 1960 to 1981. The equations are linear in the variables. The entire model contains approximately 1200 equations and is solved using the Gauss-Siedel iterative procedure.

13. The countries and regions defined in the model are shown in Table 2. The selection of countries to model individually was made on the basis of three criteria: 1) similar economic and political structure; 2) geographical location; and 3) importance to global trade for the commodities.

TABLE 2: Model Regions

Country/Region	Countries
Industrial Countries	
Australia	Australia
Canada	Canada
EC-10	Belgium, France, Italy, Luxembourg, Netherlands, W. Germany, United Kingdom, Ireland, Denmark, Greece
Japan	Japan
Other Industrial Countries	Austria, Finland, Iceland, Malta, Norway, Portugal, Spain, Sweden Switzerland, New Zealand
United States	United States
Centrally Planned Economies	
Eastern Europe	Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Yugoslavia
USSR	Union of Soviet Socialist Republic
Developing Countries	
Argentina	Argentina
Brazil	Brazil
Central Africa	Botswana, Lesotho, Namibia, Swaziland, Kenya, Malagasy Republic, Malawi, Mozambique, Tanzania, Uganda, Zambia, Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, Ethiopia, Djibouti, Benin, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Mauritius, Niger, Reunion, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Togo, Upper Volta, Zaire, Zimbabwe

.../

.../Table 2 continued

China	China
East Asia	Burma, Kampuchea, Laos, Vietnam, Hong Kong, Singapore, South Korea, Brunei, Malaysia, Philippines, North Korea, Mongolia,Pacific Islands, Papua New Guinea, Fiji Islands
Egypt	Egypt
India	India
Indonesia	Indonesia
Latin America and Caribbean	Bahamas, Barbados, Bermuda, Belize, Other Caribbean Islands, Cuba, Dominica, Dominican Republic, Jamaica, Trinidad and Tobago, Honduras, Nicaragua, Panama, Costa Rice, El Salvador, Guatemala, Haiti, Bolivia, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Surinam, Uruguay, Venezuela
Mexico	Mexico
Nigeria	Nigeria
North Africa & Middle East	Algeria, Bahrain, Cyprus, Iran, Iraq, Israel, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates, Jordan, Lebanon, Morocco, Syria, Tunisia, Turkey, Yemen A.R., Yemen D.M.
Pakistan	Pakistan
South Asia	Afghanistan, Bangladesh, Bhutan, Nepal, Sri Lanka
Thailand	Thailand

Source: EPDCS.

III. SUPPLY

14. The supply model consists of three separate components corresponding to the decision sequence of producers. First, a total cropland equation is estimated for each country or region to capture the quantity of cropland harvested for the four model commodities; second, the allocation of this land among the commodities is estimated; and third, a yield equation is estimated for each commodity. Production for each commodity is the product of the area harvested and yield equations.

15. The two-stage specification of the cropland harvested of each crop attempts to separate the short-term and long-term decisions faced by producers. The short-term decision involves allocating cropland among closely competing crops. This decision can be made and implemented very rapidly and the decision can be reversed in a future year at very little cost. Rigidities are imposed on the decision by different machinery requirements for each crop and the competition for a scarce resource such as labor availability at peak load periods, but switching of land between crops is generally possible.

16. The decision of how much total land to plant to crops is a long-term decision because of the capital investment required to prepare land for planting. The decision to expand cropland requires that land be taken out of its alternative use (e.g. forestry) and cleared, plowed and harrowed so that it can be planted. This process requires an investment of labor and capital. Once land is prepared for cropping, the subsequent investment required to keep the land under crops is small. Consequently, the decision to expand cropland involves an initial outlay plus the loss of revenue from the previous land use. The decision is often irreversible in the short run. Timber, for example, is not an annual crop and cannot be interchanged with an annual crop.

A. Total Cropland

17. The expansion of total cropland which a producer will undertake can be viewed as an optimal investment problem. It is assumed that the producer will attempt to maximize the following function:

$$\pi_t = f(\sum_i \Delta P_i/(1 + r)^i, C_t)$$

where $\sum_i \Delta P_i/(1 + r)^i$ is the discounted incremental profit flow expected from planting the land to crops rather than its previous use. The one-time capital investment required to prepare the land for crops is denoted by C_t.

18. This investment function suggests that an estimated total cropland equation should contain variables to measure the profitability of crops, the profitability of alternative land uses, and the capital cost of land preparation. Based on these assumptions, the cropland equation is specified as follows:

$$TCHA_t = f(TCHA_{t-1}, DTCRV_{t-1}, DBP_{t-1}, TGES_{t-1}, TIME)$$

where

$TCHA_t$ is the harvested area in year t for all commodities modeled.

$DTCRV_{t-1}$ is the weighted revenue per hectare based on world prices of the crops expressed in constant local currency in year t-1.

DBP_{t-1} is the world beef price expressed in constant local currency in year t-1

$TGES_{t-1}$ is the sum of wheat, coarse grain and rice ending stocks in year t-1

TIME is a linear trend with 1960 = 1, 1961 = 2, etc.

The lagged total cropland, $TCHA_{t-1}$, is included to reflect the partial adjustment of cropland toward the desired level. The arguments for this specification are well known and date back to Nerlove's work on agricultural supply response (Nerlove, 1958). The variable $DTCRV_{t-1}$ reflects the weighted revenue per hectare received from all crops in the previous year. The prices used to calculate this variable are the international prices. The yields are the actual country yields and the weights are based on the area harvested of each of the crops. This variable does not capture the profitability of crop production since no cost information is included, however, it is a superior specification to prices since it reflects yield increases over time. The lagged form of the variable is included to proxie farmer's expectations of future revenues. This variable may also be measuring capital availability which may be a factor in an investment decision. The variable is converted into local country currency and deflated by the country consumer price index.

19. The world beef price was included to capture the value of using the land for pasture. Price rather than revenue is used because estimates of beef produced per unit of land are not available, and because the efficiency of beef production has not changed significantly over time. A linear trend is included to capture unknown factors such as government land development programs which are independent of year-to-year changes in commodity prices or profitability.

20. A final variable, not suggested by the theoretical model, is also included in the estimated equation. This variable is total grain ending stocks (wheat, coarse grain and rice) in the region in the previous year. It is included to measure local food stock conditions. It is significant in a number of countries. The negative sign indicates that low grain stocks in the previous year result in expanded total cropland in the next year. This result would be consistent with a subsistence type agriculture where low stocks increase the risk of lower food consumption. It is also consistent with an exporting country which attempts to maintain an inventory for exports.

21. The land preparation costs suggested by the theoretical model were not included because of lack of data. However, at a future time this variable will be explored using wage rates and other proxie variables. Interest rates were included in several preliminary specifications, but were consistently of the opposite sign from that expected.

22. An alternate functional form of the total crop revenue and beef price variables which was used in some specifications was to include these variables in ratio form rather than separately. While not the preferred specification, this alternative has the advantage of eliminating the exchange rate and consumer price index from the equation. It worked better for countries which have had very high inflation rates and rapidly falling currency values. An undesirable characteristic of this functional form is the forced equality of the response of area to both total crop revenue and beef prices.

B. Harvested Area

23. Harvested area of each crop is estimated as a function of total cropland harvested and relative commodity revenues. This specification treats the determination of harvested area as a short run allocation decision, given that the decision of how much cropland to plant has already been made. The specified equation is:

$$HA_{i,t} = f(TCHA_t, HA_{i,t-1}, RV_{i,t-1}, RV_{j,t-1}, TIME)$$

where

$HA_{i,t}$ is the harvested area of commodity i in year t

$TCHA_t$ is the total cropland harvested in year t of wheat, coarse grains, rice and soybeans

$RV_{i,t}$ is the revenue of commodity i in year t

TIME is a linear trend with 1960=1, 1961=2, etc.

24. The lagged dependent variable, $HA_{i,t-1}$, was included to represent the partial adjustment toward a desired area harvested. The inclusion of this variable is based on theoretical arguments offered by Nerlove and others. The lagged crop revenues are included to represent the relative profitability of competing crops. Revenues rather than prices are used to allow changing crop yields to be reflected in both the historical estimates and in projections. Finally a linear trend, TIME, is included to capture unknown factors or factors which are known to be important, but which cannot be included due to data limitations. One of these known but not included factors is production costs. Ideally, net profits should be used rather than revenues. By excluding production costs, the assumption is being made that costs are growing proportionately to revenues. This is not true. The costs of producing some crops, such as those which require large amounts of fertilizers and chemicals, are growing more rapidly than other crops. A linear trend allows some of these omitted variables to be captured but not identified.

C. Crop Yields

25. Crop yields are assumed to be influenced by seed quality, inputs such as fertilizer, land quality and weather. The estimated yield model necessarily simplifies these factors into variables which can be used to represent the various factors. The model is:

$$YD_{i,t} = f(TIME, RPF_{i,t-1}, HA_{i,t}, HYV_{i,t})$$

where

$YD_{i,t}$ is the yield per hectare in year t of commodity i

TIME is a linear trend with 1960=1, 1961=1, etc.

$RPF_{i,t-1}$ is the lagged ratio of the price of the commodity i to the price of fertilizer.

$HA_{i,t}$ is the area harvested of the commodity i in year t

$HYV_{i,t}$ is the percent of total area planted to the high-yielding varieties

26. The linear trend, TIME, is included to measure the genetic improvement in seed over time. Doing so assumes that the contribution of plant breeding research to yields is growing at a constant amount per year. An alternative assumption which should be considered is that a yield limit exists and yields increase at a decreasing rate. If this is the case yields would increase along a nonlinear or perhaps log linear path. The selection of the appropriate yield model can be based on both empirical observation and agronomic research. Yield experiments conducted by plant breeders provide some evidence of whether leveling-off of yields is being observed. As reported by Menz and Pardey (1983), agronomic trials do not indicate any plateau in US corn yield gains, and the evidence suggests linear growth.

27. For many countries data is very difficult to obtain on rates of fertilizer application. In order to capture the contribution of fertilizer to yields, the ratio of world crop price to world fertilizer price was used. This variable attempts to measure the incentives for farmers to apply fertilizer, considering both the price of fertilizer and the price of the crop.

28. Three different variables are used to measure the influence of fertilizer and crop prices on yields. In one form, the ratio of last year's crop to last year's fertilizer price is used. Secondly, last year's crop price is divided by the current year's fertilizer price; and finally, current crop prices are divided by current fertilizer prices. The appropriate variable to use depends on two factors, the availability of information and the speed of adjustment. The first variable, last year's crop price divided by the current year's fertilizer price assumes that at the time of fertilizer application,

farmers do not know the current crop price but they do know the current year fertilizer price. The third-mentioned form of the variable is only appropriate in Southern Hemisphere countries where crops are planted after the Northern Hemisphere crops are harvested. Consequently, farmers are able to estimate the current year price very well. This specification is applied to crops grown in Argentina, Australia, Brazil and South Africa.

29. The third factor influencing crop yields is the quality of land. In general, the quality of land should be inversely related to the quantity of land planted. As more and more land is planted, farmers will be using less productive land. Since not all countries have changed their crop area significantly over the last two decades, we would not expect yields to respond to this variable in all countries. Further, it is often statistically difficult to separate the negative influence of lower quality land from the positive influence of genetic yield gains.

30. The introduction of the high-yielding varieties (HYVs) represents a movement to a higher yield curve. In some cases the new varieties were able to produce twice the amount of the traditional varieties. In order to account for this shift, the HYV variable was included directly in the yield equation. When data was not available on the level of HYV use, a proxie variable was used to represent the adoption of the HYVs.

IV. IMPORT DEMAND

31. The demand for imports can be viewed in general as a function of income, prices and relevant demand shifters

$$M_{i,t} = f(Y_t, P_{i,t}, P_{j,t}, Z_t)$$

where $M_{i,t}$ is per capita imports of commodity i, Y_t is real per capita income, $P_{i,t}$ is the real import price of commodity i, $P_{j,t}$ is the real price of a related commodity j, and Z_t is a set of relevant demand shifters. This basic import demand model has been presented by Leamer and Stern (1970), Labys (1973) and others. The specific functional form, relevant variables and expected results are dependent upon the characteristics of the commodity being imported, the nature of use of the imported commodity, the structure both of the international market and the domestic market and many other factors.

32. In this study the demand for grain imports is treated as the independent demand for each of the primary grain categories--wheat, rice, coarse grains, soymeal and soyoil. 1/ In many cases, an importing country both produces and imports the commodity, and in some cases a country will produce, import and export the commodity. This latter case can occur for several reasons. First, a large country may import in one geographic region while exporting from another. This kind of activity occurs between the United States and Canada, with the United States importing feed grains along the Canadian border and exporting through the Gulf. Seasonal supply availabilities may also cause an exporting country to import during certain periods of the year. Finally, differences in grain quality and varieties may cause a country to

---

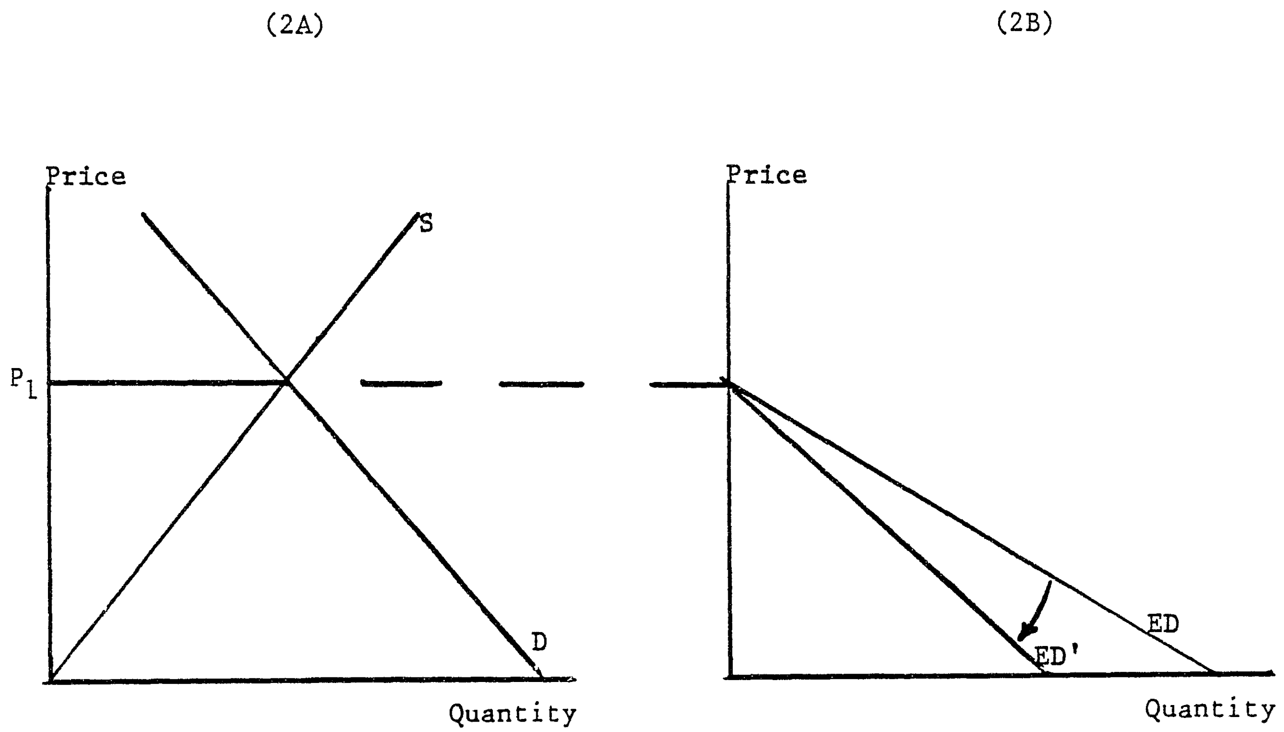
1/ Although a system of demand equations which estimates the total demand for grains as well as the demand for individual grains is probably desirable, it has not been undertaken in this study.

both import and export grain. The EEC, for example, produces, consumes and exports soft wheat while importing hard wheat. The soft wheat is used primarily for noodles, pastries and quick bread while the hard wheats are used for yeast breads and hard rolls.

33. An explanation of the occurrence of both imports and exports within the same year will not be pursued here. In order to avoid these issues, other researchers have chosen instead to study the net-import demand for grain. This approach has merit to the extent that imported and domestic goods are substitutes. If the imported good does not substitute for the domestically-produced good, no amount of change in domestic production will affect the demand for imports. Alternatively, if the imported and domestic good are identical, domestic and imported goods are perfect substitutes and a unit of imported grain will exactly offset a unit of domestically produced grain.

34. Because of the small size of their imports relative to total world demand, most importing countries can be assumed to face a perfectly elastic supply at a given price. If imports and domestic goods are regarded as perfect substitutes, import demand can be viewed as an excess-demand schedule. Consider Figure 2. Domestic demand and supply are shown in Figure 2A as D and S respectively. The difference between D and S below P_1 is the excess demand schedule, ED in Figure 2B, or equivalently the demand for imports. At a price below P_1, domestic demand exceeds domestic supply and ED shows the imports required to satisfy domestic demand. If the imported and domestically produced goods are perfect substitutes and if free trade prevails, then imports, M, will equal ED.

FIGURE 2: IMPORT DEMAND



Therefore, domestic supply will directly influence imports and the import-demand function should include domestic supply variables directly (see Leamer and Stern, 1970, p. 11 for a discussion of this specification).

35. With trade barriers the excess demand curve will be rotated to ED'. This situation can be written as

$$ED' = F(ED, G)$$

where the excess demand curve depends on the difference between domestic demand and supply and a set of government variables, G. Examples of such government variables could be import duties, foreign exchange constraints or a government budget constraint.

36. A dynamic specification of import demand is appropriate when demand in any period is assumed to adjust only partially toward desired or equilibrium demand. Government restrictions could also delay the adjustment of demand to changes in the underlying demand determinants. Partial adjustment to some desired level can be modeled using the Koyck lag specification of a lagged dependent variable as an explanatory variable. However, this specification may have another valid interpretation. That is, the use of an imported good as an input into a production process could cause the level of imports to depend on past levels of imports. This occurs when imports have contributed importantly to the size of an end-use industry and their continuation is necessary to maintain the industry. The feeding of livestock is an example.

37. Foreign exchange availability has been suggested as an important determinant of import demand by a number of authors including Leamer and Stern (1970), Hemphill (1974), Abbott (1979). The importance of foreign exchange as a constraint may have increased in recent years, at least among the developing countries, following the worsening in debt-servicing ability by these countries.

38. Finally, a variable which may also influence grain-import demand is the level of food aid. This variable is relevant for many developing countries and should act as a demand shifter causing imports to increase beyond the levels which would have been imported without food aid. One of the most significant food aid programs is the P.L. 480 program of the United States.

39. The framework of the import model can be stated as a reduced form of a standard residual trade model. Consider the following model:

$$PROD_t = \beta_0 + \beta_1 PF_{t-1} + \beta_2 PROD_{t-1} \quad (1)$$

$$STK_t = \alpha_0 + \alpha_1 PF_{t-1} \quad (2)$$

$$DD_t = \gamma_0 + \gamma_1 Y_t + \gamma_2 PR_t \qquad (3)$$

$$PF_t = T_1 + T_2 PW_t \qquad (4)$$

$$PR_t = \delta_1 + \delta_2 PW_t \qquad (5)$$

$$M_t = \pi_0 + \pi_1(DD_t - PROD_t - STK_t + STK_{t+1}) - \pi_2 G_t \qquad (6)$$

where

$PROD_t$ is production in year t

PF_t is the real farm price in year t

STK_t is the level of beginning stocks in year t

DD_t is the level of domestic demand in year t

Y_t is real per capita income in year t

PR_t is the real retail price in year t

M_t is the level of imports in year t

PW_t is the world price expressed in local currency and deflated by consumer price index in year t

G_t is other factors which influence imports such as a country's balance of payments, in year t

All quantities are assumed to be expressed on a per capita basis and all prices are in real terms. Transportation costs are assumed to be zero. Equation (1) is a simple production model in which production depends on farm prices in the previous period and on last year's production. Equation (2) is a stock equation which specifies the level of stocks available in period t as dependent on prices in year t-1. Domestic demand, equation (3), is a function of income, population and retail price. Equations (4) and (5) reflect the relationship between farm and retail price and the world price. Finally, equation (6) expresses the level of imports as a function of the level of excess demand, the world price and other relevant variables such as the balance of payments. Assume that production and stocks are predetermined in any given year. Substituting equations 1-5 into equation (6) and rewriting, we have:

$$
\begin{aligned}
M_t = {} & \pi_0 \\
& + \pi_1(\gamma_0 + \gamma_1 Y_t + \gamma_2(\delta_1 + \delta_2 PW_t) \\
& - \pi_1 \overline{(PROD_t} + \overline{STK_t)} \\
& + \pi_1(\alpha_0 + \alpha_1(T_1 + T_2 PW_t) - \pi_2 G_t
\end{aligned} \tag{7}
$$

or

$$M_t = \omega_0 + \omega_1 Y_t + \omega_2 PW_t + \omega_3 (\overline{PROD}_t + \overline{STK}_t) + \omega_4 G_t \tag{8}$$

where

$$\omega_0 = \pi_0 + \pi_1\gamma_0 + \pi_1\gamma_2\delta_1 + \pi_1\alpha_0 + \pi_1\alpha_1 T_1$$

$$\omega_1 = \pi_1\gamma_1$$

$$\omega_2 = \pi_1\gamma_2\delta_2 + \pi_1\alpha_1 T_2$$

$$\omega_3 = \pi_1$$

$$\omega_4 = \pi_2$$

40. Equation (8) is a reduced-form import demand equation which can be estimated directly. It is difficult to interpret the individual coefficients, however, we can infer the sign of most of the variables. Income should have a positive sign, production plus stocks should have a negative sign as should current world price. The intercept term and the exogenous variable G_t may have either a positive or negative sign.

41. The direct estimation of an import equation is not without problems. However in spite of these problems, this approach produces a useful model for forecasting imports of a country or region. Abbott (1979) has pointed out some

of the advantages and disadvantages of using this approach. One of the advantages of the import-demand approach is that the direct estimation of trading behavior requires little knowledge of individual country's policies. This is important when a large number of countries are being studied as is the case in building a world model. It is also essential when regions are being considered since the government policies of a region are nearly impossible to define.

42. A second advantage of the import-demand model is that the government is treated endogenously in the determination of the level of imports. This corresponds to the decision-making structure regarding the level of imports in the majority of countries. It also indicates that the coefficients of the import-demand equation reflect the response of the government importing agency. Variables which would influence a government decision maker can also be explicitly included as explanatory variables. These types of variables cannot be easily included in the more traditional trade models.

43. The import-demand approach does have limitations which need to be recognized. Since the estimated equation is a reduced form, interpretation of the parameters is difficult. The structural form model which yields the reduced form is unknown and incorrect conclusions about the contribution of a particular variable are more likely to occur. Another problem occurs because the parameters are policy dependent. Whenever the policies of a country change, the parameters also change. As a consequence, estimation of the import demand equations requires stable country policies. At the very least, this problem requires some attention and caution in the use of import equations under unstable policy conditions.

44. The elasticity of demand for imports taken from the excess demand curve is:

$$E_{ED} = \frac{\partial ED}{\partial P} \cdot \frac{\bar{P}}{\bar{Q}_I}$$

where $\bar{Q}_I$ is the mean quantity imported and $\bar{P}$ is the mean price. This can be stated in terms of domestic demand and supply elasticities as:

$$E_{ED} = E_D \frac{\bar{Q}_D}{\bar{Q}_I} - E_S \frac{\bar{Q}_S}{\bar{Q}_I}$$

Therefore, the elasticity of excess demand is equal to the elasticity of demand times the ratio of quantity demanded to the quantity imported minus the elasticity of domestic supply times the ratio of domestically produced to imported quantities.

45. The E_{ED} will equal E_D when $Q_S = 0$ or $E_S = 0$ and E_{ED} will be more elastic than E_D in all other cases. Suppose $E_S = 0$, domestic supply is perfectly inelastic - the situation which exists in the short run for production of an annual crop such as wheat. The elasticity of excess demand is then given by

$$E_{ED} = E_D \cdot \frac{\bar{Q}_D}{\bar{Q}_I}$$

or it is equal to domestic demand times the ratio of quantity demanded to imports. If imports represent half of total quantity demanded, E_{ED} would be twice E_D.

46. The import equation (8) expresses imports as a function of income, domestic supply, the import price and a government variable. An expanded version of this model was estimated for each of the three grain types. The estimated equation allows for cross price effects and domestic substitution between grains and is estimated on net imports. The model is also specified as a dynamic model to allow for a partial adjustment to changes in the independent variables. The estimated model is:

$$NI_{i,t} = f(Y_t, DS_{i,t}, DS_{j,t}\ P_{i,t}, P_{j,t}, TB_t, NI_{i,t-1})$$

where

$NI_{i,t}$ is per capita net imports of commodity i in year t

Y_t is per capita real gross domestic product in year t

$DS_{i,t}$ is per capita domestic supply (production plus beginning period stocks) of commodity i in year t

$DS_{j,t}$ is domestic supply of a substitute commodity j in year t

$P_{i,t}$ is the world price of commodity in year t in US dollars expressed in the country currency and deflated by the country's consumer price index

$P_{j,t}$ is the price of a substitute commodity j in year t

TB_t is the per capita merchandise trade balance in year t measured in country currency and deflated by the country's consumer price index

An additional variable, food aid shipments, was included when data were available.

V. EXPORT SUPPLIES

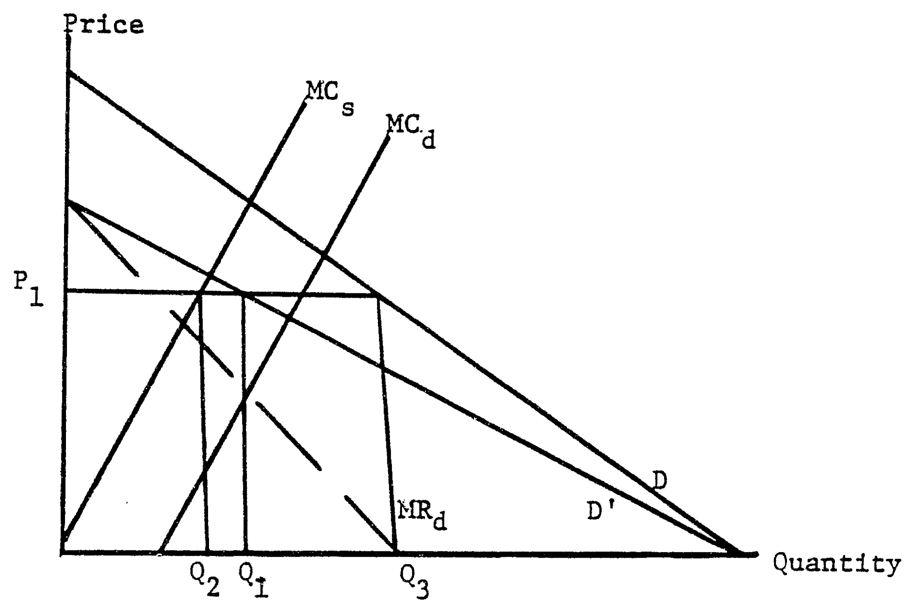
The structure of the world grain export market has been described by various authors as oligopolistic with price leadership provided by one or several of the major exporting countries. McCalla (1967) described the world wheat market as a duopoly with price leadership provided by Canada. Alaouze, Watson and Sturgess (1977) described the wheat market as a triopoly involving the United States, Canada and Australia. Bredahl and Leonardo (1983) tested a US residual supplier model for coarse grain exports.

Grain and soybean exports are dominated by a few countries. The five largest exporters provided 73.3% of the total rice exports, 94.2% of the total wheat exports, 84.4% total coarse grain exports and 98% of the total soybean exports over the 1979-81 period. The United States was the largest exporter, providing 65.3% of the coarse grain exports, 45.3% of the wheat exports, 58% of the soy product exports and 23.2% of the rice exports over the 1979-81 period.

Because of the small number of countries which supply the majority of exports, the oligopoly model provides a useful beginning point for analysis of exports. An oligopoly exists when more than one seller is in the market, but when the number is small enough so that any seller can influence the market. Because of the small number of sellers, each seller is expected to be aware of the actions of its rival and of their reactions to changes in policy. Many different market outcomes are possible from an oligopoly model ranging from competition to collusion.

Suppose the market consists of one dominant firm and a number of smaller firms. The dominant firm may or may not be the low-cost producer in the market. For political or other reasons, the dominant firm may decide to set the market price and let the small firms sell all they wish at that price. The small firms will behave as perfectly competitive suppliers and regard their demand curve as perfectly elastic at the price set by the dominant firm. The problem facing the dominant firm is to determine price so as to maximize profits while allowing the small firms to sell as much as they wish. Consider Figure 3. The market demand curve is D, and the marginal cost curve of the dominant firm is MC_d. The summation of the marginal cost curves of all small firms is MC_s.

FIGURE 3: DOMINANT FIRM OLIGOPOLY MODEL

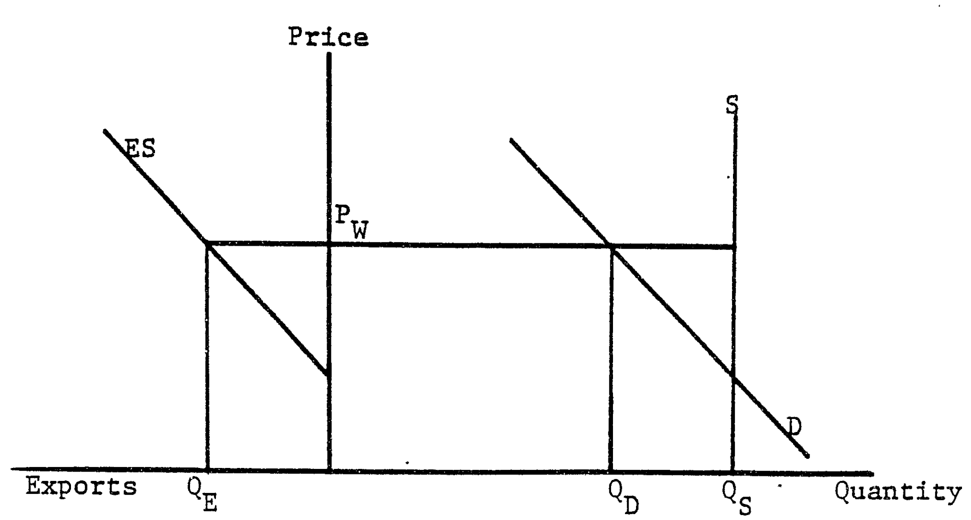


The dominant firm will maximize profits by equating its marginal cost with its marginal revenue curve, after allowing the small firms to sell their desired amounts. In Figure 3, this occurs by equating MC_d and MR_d to sell a total output of Q_1 at a price of P_1. The small firms will supply Q_2, while the dominant firm provides Q_1. Total sales will be $Q_1 + Q_2 = Q_3$.

51. This basic model provides a reasonable model of the world grain and soybean markets. Two basic tenants of this model are price leadership and the granting of market access by the dominant firm to the smaller firms. Consider how closely this conforms to the world grain markets. The United States is the dominant exporter and sets price bounds by its government programs, allowing price to fall as low as the loan rate after which grain is bid into the government storage program. If price rises beyond a certain level, the stocks are released back onto the market. Thus, a price band is provided to the world market through the United States' government program. Other exporting countries can and do export as much as desired, with occasional pressure from the United States. Argentina, for example, increased coarse grain exports from 5.3 million tons in 1979/80 to 14.2 million tons in 1980/81 when the United States embargoed grain sales to the USSR.

52. In this form of oligopoly the behavior of the small firms is that of a price-taker. The small firm accepts the world price as set by the dominant firm and maximizes profits by supplying the quantity where marginal cost equals world price. The application of this model to exports is shown in Figure 4.

FIGURE 4: SMALL COUNTRY EXPORTER



Domestic supply is shown by S, and is fixed within a given marketing year. Domestic demand is given by D. At an export price above the level where domestic demand is equal to domestic supply, the country will export (ignoring differences between country and world prices). The excess supply curve, ES, is equal to S - D and shows the level of exports. At the world price P_W, domestic demand is given by Q_D, exports are equal to Q_E which is also $Q_S - Q_D$.

53. The elasticity of export supply can be obtained from examining the elasticity of the ES curve.

$$E_{ES} = \frac{\partial ES}{\partial P} \cdot \frac{\bar{P}}{\bar{Q}_E}$$

Restating in terms of domestic demand, supply and domestic elasticities, we have:

$$= E_S \frac{\bar{Q}_S}{\bar{Q}_E} - E_D \frac{\bar{Q}_D}{\bar{Q}_E}$$

Therefore the elasticity of the excess supply curve is given by the elasticity of domestic supply weighted by the ratio of domestic supply to exports minus the elasticity of domestic demand weighted by the ratio of domestic demand to exports. In the short run, the elasticity of domestic supply is zero and the elasticity of the excess supply curve is

$$E_{ES} = - E_D \frac{\bar{Q}_D}{\bar{Q}_E}$$

The elasticity of excess supply is equal to the negative of the elasticity of domestic demand weighted by the ratio of domestic demand to exports. Since the elasticity of demand is negative, the elasticity of excess supply becomes positive.

54. Following the dominant firm oligopoly model of the world grain and soybean market, the export supply curves for the exporting countries is:

$$X_{i,t} = DS_{i,t} - DD_{i,t} - STK_{,t+1}$$

where

$X_{i,t}$ is the exports of commodity i in year t

$DS_{i,t}$ is the domestic supply (production plus beginning stocks) of commodity i in year t

$STK_{i,t}+1$ is the beginning stocks of commodity i in year t

The functional relationships can be described as

$$DS_{i,t} = PROD_{i,t} + STK_{i,t}$$

$$DD_{i,t} = f(Y_t, P_{i,t}, P_{j,t})$$

$$STK_{i,t} = f(Y_t, P_{i,t}, P_{j,t}, DD_{i,t-1})$$

where $DS_{i,t}$ is per capita domestic supply and is predetermined; domestic demand, $DD_{i,t}$, is defined as per capita demand which depends on real per capita income, Y_t, and real prices of commodity i and a related commodity j; per capita ending stocks, $STK_{i,t}$, are a function of real per capita income, relative prices and an inventory holding level which depends on domestic demand in the previous year.

55. All exporters of wheat, rice, coarse grains, soymeal and soyoil are treated as small country exporters, except for the United States. Exports from the United States are equal to the residual required to balance world net imports and exports. This configuration corresponds with actual market behavior since the early 1970s.

V. CONSUMPTION

56. In the importing countries and regions, consumption is calculated as the residual with production, net imports and stocks being estimated. For the exporting countries, consumption is estimated directly. In these countries, consumption is disaggregated into two final uses: feed and all other. Per capita consumption is then estimated as a function of income and relevant prices:

$$CF_{i,t} = f(Y_t, P_{i,t}, P_{j,t})$$

$$CO_{i,t} = f(Y_t, P_{i,t} P_{j,t})$$

where $CF_{i,t}$ and $CO_{i,t}$ are per capita food and all other consumption of commodity i respectively. Y_t is real per capita income and $P_{i,t}$ and $P_{j,t}$ are the real prices of the commodity i and a related commodity j.

VI. STOCKS

57. In order to close each country model, the final component which must be estimated is the level of ending stocks (next years' beginning stocks). The ratio of ending stocks to domestic consumption in the previous year is estimated. The equation is

$$\frac{STK_{i,t}}{DD_{i,t-1}} = f(P_{i,t})$$

where

$STK_{i,t}$ is the level of ending stocks of commodity i in year t

$P_{i,t}$ is the real price of commodity i in year t

Previous experience has shown that this type of model will perform reasonably well, but will not capture totally the volatilability which is frequently present in stock holdings.

VIII. PRICES

58. A single world price, the US export price in dollars, is assumed to exist for each of the commodities. Each country's border price is then equal to the world price expressed in constant units of local currency.

$PW_{i,t}$ = U.S. export price of commodity i in year t

$P^k_{i,t}$ = border price of country k for commodity i in year t

$= PW_{i,t} * XR_{k,t} / CPI_{k,t}$

where $XR_{k,t}$ is the exchange rate of country i relative to the US dollar, and $CPI_{k,t}$ is the consumer price index of country k in year t

59. The model is solved for the world price which equates net imports with net exports. A price equation is used to solve for the equilibrium world price. This approach has been used extensively in recent years. A discussion of the advantages of the use of a price equation can be found in Hein (1977).

60. The price equation used in the model is designed to reflect the role of U.S. government policy as the determinant of the U.S. and world price floor. This occurs because of the loan rate programs of the United States which bids grain away from the world market at the price floor or loan rate. Under the current program, the US government allows farmers enrolled in the program to place their grain in government storage and receive a low interest loan against the commodity. This loan is made at a rate, the loan rate, which is intended to reflect the cost of production for US farmers. In effect, the loan rate sets the floor on the US and world markets since US farmers will opt for the government program if the price falls to the level of the loan rate. This places a floor on the price of US exports and unless supplies are extremely large, the floor will also support the world price.

The US export price equation for each grain is estimated as

$$PW_t = f(LR_t, SU_t)$$

where

LR_t is the US farm loan rate expressed in nominal dollars

SU_t is the ending world stocks relative to utilization in the previous year

IX. ADDITIONAL WORK

61. A model which is used is constantly evolving and changing. This version of the world grain and soybean model has several features which will be changed in subsequent versions. The first improvement which will be undertaken is to include country specific data to a greater extent. Producer prices of crops and inputs will be included for the largest countries. This will allow a greater range of policy simulations. It hopefully will also permit more accurate price and trade forecasts.

62. A second change, which would represent a major effort and hopefully a major advance would be to endogenize the macro-economic variables for key countries. This step is especially important for countries in which agricultural production represents a major component of national income. This activity will be pursued on an individual case basis with the most important countries considered first.

References

Abbott, Philip C., "Modeling International Grain Trade with Government Controlled Markets," American Journal of Agricultural Economics, Vol. 61, No. 1, pp. 22-31, February 1979.

__________, "The Role of Government Interference in International Commodity Trade Models," American Journal of Agricultural Economics, Vol. 61, No. 1, pp. 135-139, February 1979.

Alaouze, Chris M., A.S. Watson and N.H. Sturgess, "Oligopoly Pricing in the World Wheat Market," American Journal of Agricultural Economics, Vol. 60, No. 2, May 1978, pp. 173-185.

Askari, H., and J. Cummings, Agricultural Supply Response: A Survey of the Econometric Evidence, Praeger Publishers, 1976

Bjarnason, Harold F., "An Economic Analysis of 1980 International Trade in Feed Grains," unpublished Ph.D. dissertation, University of Wisconsin, 1967.

Brandow, A.E., "A Note on the Nerlove Estimate of Supply Elasticity," Journal of Farm Economics, Vol. 40, August 1958.

Bredahl, M.E., W.H. Meyers, and K.J. Collins, 1979, "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity," American Journal of Agricultural Economics 61 (1979): 58-63.

Bredahl, M. E. and Leonardo Green, "Residual Supplies Model of Coarse Grain Trade," American Journal of Agricultural Economics, Vol. 65, No. 4, November 1983, pp. 785-790.

Capel, R.E., and L.R. Rigaux, 1974, "Analysis of Export Demand for Canadian Wheat," Canadian Journal of Agricultural Economics 22 (July): 1-14.

Chambers, Robert G. and Richard E. Just, "Critique of Exchange Rate Treatment in Agricultural Trade Models," American Journal of Agricultural Economics 61(1), Feb. 1979, pp. 249-57.

Falcon, Walter P. and Eric A. Monke, "International Trade in Rice," Food Research Institute Studies, Vol. XVII, No. 3, 1979-80, pp. 279-306.

Grennes, Thomas, Paul R. Johnson and Marie Thursby, "Devaluation, Foreign Controls and Domestic Wheat Prices," American Journal of Agricultural Economics 59 (1977), pp. 619-27.

Hemphill, William, "The Effects of Foreign Exchange Receipts on Imports of Less Developed Countries," International Monetary Fund Staff Papers, Vol 21, pp. 637-77, 1974.

Jabara, Cathy L., "Trade Restrictions in International Grain and Oilseed Markets," USDA, ESS, Foreign Agricultural Economic Report No. 162, January 1981.

Johnson, P.R., 1977, "The Elasticity of Foreign Demand for U.S. Agricultural Products," American Journal of Agricultural Economics 59 (November): 735-736.

Labys, Walter C., Dynamic Commodity Models: Specification, Estimation, and Simulation, Lexington Books, 1973.

Leamer, Edward E. and Robert M. Stern, Quantitative International Economics, Aldine Publishing Co., 1970.

McCalla, Alex F., "A Duopoly Model of World Wheat Pricing," Journal of Farm Economics, Vol. 48, 1966, pp. 711-727.

Menz, Kenneth M. and Phillip Pardey, "Technology and U.S. Corn Yields: Plateau and Price Responsiveness," American Journal of Agriculatural Economics, August 1983, pp. 558-562.

Nerlove, M., The Dynamics of Supply: Estimation of Farmers' Response to Price," Johns Hopkins University Press, 1958, Baltimore, MD.

________________, "Estimates of Supply of Selected Agricultural Commodities," Journal of Farm Economics, Vol. 38, 1956, pp. 496-509.

________________, "On the Nerlove Estimate of Supply Elasticity: A Reply," Journal of Farm Economics, Vol. 40, August 1958.

Nerlove, M. and W. Addison, "Statistical Estimation of Long-Run Elasticities of Supply and Demand," Journal of Farm Economics, Vol. 40, November 1958.

Schmitz, Andrew and Donald G. Watts, "Forecasting Wheat Yields: An Application of Parametric Time Series Modeling," American Journal of Agricultural Economics, Vol. 52, No. 2, 1970.

Schuh, G. Edward, "The Exchange Rate and U.S. Agriculture," American Journal of Agricultural Economics, February 1974, 56(1), pp. 1-13.

Tweeten, L.G. 1967, "The Demand for United States Farm Output" Stanford Food Research Institute Studies 7: 343-369.

Walsh, "Response to Price in the Production of Cotton and Cottonseed, "Journal of Farm Economics, Vol. 26, 1940, pp. 359-372.

Zwart, A.C., and K.D. Meilke, 1979. "The Influence of Domestic Pricing Policies and Buffer Stocks on Price Stability in the World Wheat Industry," American Journal of Agricultural Economics 61 (August) 434-447.

USDA, Alternative Futures For World Food in 1985, ESS, FAE NO. 151, June 1981.

World Development Report, 1984, The World Bank, Oxford University Press, July 1984.

APPENDIX A

Data Sources and Definitions

The primary historical data sources are the World Bank, International Monetary Fund, FAO and the US Department of Agriculture.

A single world rice, wheat and corn and soybean price is used in the model. The wheat price is the US No. 1 HRW, Ordinary Protein, FOB Gulf, July-June year. The rice price is the US No. 2 Long Grained, Milled, Bagged, FOB Houston, Aug-July year. The corn price (which is a proxy for all coarse grains) is US No. 2 Yellow, FOB Gulf, Oct-Sept year. The soybean price is the U.S. No. 2 Yellow, FOB Gulf, Oct.-Sept. The real border price for each country is then used for estimation and is defined as the world price multiplied by the exchange rate and deflated by the country's consumer price index.

The grain and soybean data is taken from the Foreign Agriculture Service of the US Department of Agriculture. All data are on a crop year basis and are measured in thousand metric tons or thousand hectares.

The macro economic and demographic data are taken from the World Bank data base and the International Financial Statistics (International Monetary Fund). Population is in millions, income is gross domestic product measured in billions of local currency. The exchange rate is measured in units of local currency per US dollar, and the consumer prices are an index. All these data are taken from the IFS or from the World Bank data base. The trade balance is FOB Exports minus FOB Imports in millions of US dollars and is from the IFS.

Finally data for the USSR, Eastern Europe and China are defined differently from the data used for other countries. The exchange rate and consumer price indexes were not used. Equations were estimated on real US commodity prices and real income based on World Bank data.

The regional data are obtained by aggregating country data for variables with common units, i.e., tons, hectares, persons. Regional GDP is obtained by converting local currency GDP to US dollars using a 1971-80 average exchange rate and then aggregating. Regional exchange rate and consumer price indexed are constructed as a weighted average of the largest countries in each region. Because the exchange rate and consumer price index data are the most incomplete of the data series used in the model, this approach was the only alternative for regions comprised of many small countries. The food aid data was from the FAO publication Food Aid in Figures, 1983, and from the USDA for years prior to 1970.