Policy Research Working Paper 10719

Environmental Policy under Weak Institutions

Cem Karayalcin
Harun Onder

WORLD BANK GROUP
Macroeconomics, Trade and Investment Global Practice
March 2024

Policy Research Working Paper 10719

Abstract

Developing countries are facing mounting pressures to incorporate environmental concerns into their policy reform agendas. This paper finds that common environmental policies, such as levying taxes to reduce the excessive exploitation of natural assets, can be self-defeating when (i) institutions are weak and (ii) the general equilibrium effects of such policy actions are overlooked. This seemingly paradoxical result is driven by fundamental mechanisms in structural transformation frameworks, without the need for strong assumptions. It also carries a clear policy implication: environmental policies should be considered within a country's broader development context, rather than in isolation.

This paper is a product of the Macroeconomics, Trade and Investment Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at honder@worldbank.org.

Environmental Policy under Weak Institutions*

Cem Karayalcin[†] and Harun Onder[‡]

Key words: Environmental Policy, Climate Change, Development
JEL codes: H23, O44, Q58

*The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors; they do not necessarily represent the views of the World Bank Group and its shareholders. We thank Tito Cordella, Richard Damania, Stefanie Onder, Sjak Smulders, and seminar participants at the International Monetary Fund and the World Bank East Asia Chief Economist Office for invaluable comments and suggestions. All errors are ours.

[†]Florida International University, Miami, FL.
[‡]Macroeconomics, Trade & Investment Global Practice, World Bank, Washington, DC

1 Introduction

Climate change is transforming the global policy agenda, with significant consequences for developing economies. On one hand, trade policy measures such as the European Carbon Border Adjustment Mechanism (CBAM) aim to facilitate pollution mitigation efforts outside advanced economies. On the other hand, growing emphasis on environmental and/or climate reforms and projects seem to reconfigure official aid to developing countries. Leaving aside any normative concerns regarding these trends, this paper focuses on a more positive inquiry: Can common institutional weaknesses in developing economies influence the effectiveness of traditional environmental policy prescriptions?

To answer this question, we utilize a simple general equilibrium model with two sectors, agriculture and manufacturing, following Matsuyama, 1992. While manufacturing only employs labor, agriculture employs both labor and a nature-based input (land). Workers are mobile across the sectors, responding solely to differences in wages. Preferences are non-homothetic, with a subsistence level of food consumption setting the income elasticity of demand for food to less than unitary. In the benchmark scenario, the economy is assumed to be closed and decentralized, with weak institutions. This entails incomplete property rights over nature-based assets, leading to dynamic distortions (over-exploitation of the natural asset from a social point of view), and administrative weaknesses such as elite capture or inefficiencies in tax collection, allowing a portion of the tax proceeds to leak out of the economy. Within this framework, we first examine the solution of the social planner, who internalizes the social cost of over-exploiting natural resources. Subsequently, we investigate whether policy makers can reduce this excessive exploitation simply by levying a tax on the natural resource-intensive sector (to be rebated to consumers) within a decentralized setup.

The analysis reveals that, under the benchmark conditions, environmental taxes can be self-defeating. That is, they can increase the exploitation of natural resources rather than decrease it, when a relatively large share of tax proceeds is lost. This seemingly paradoxical outcome is driven by three channels that are common to multi-sector general equilibrium models. First, environmental taxes reduce the marginal productivity of labor in agriculture, driving workers towards manufacturing. Second, in a closed economy, this negative supply shock leads to higher food prices, hindering the outflow of labor from the sector. Third, with non-homothetic preferences, adverse income shocks increases demand for food, reinforcing the price effect in a closed economy. Within our framework, when the leakage is large enough, the demand-side effects can dominate the supply-side effects, thereby increasing the exploitation of natural resources.

We also consider several extensions, which demonstrate that our paradoxical result is weakened by: (i) an increase in the elasticity of substitution between land and labor in agriculture, for initially small elasticities (the opposite is true for large elasticities), (ii) economic openness, which fixes prices and shuts down any demand-side considerations, completely reversing our main result, (iii) international transfers that include a larger share of the agricultural good compared to the pre-transfer market equilibrium in the receiving country, and (iv) mean-preserving inequality in income, which shifts aggregate demand towards manufacturing. In all cases, effects are manifested through the three channels identified in the benchmark model.

Our analysis contributes to an established literature on institutional quality in developing countries, including Olken and Pande, 2012 who pay special attention to the measurement of corruption along with its drivers and economic consequences. More recently Andersen et al., 2017 and Andersen et al., 2022 detect financial leakages under weak institutions in developing countries. Similarly, the relationship between development, low administrative capacity, and inefficient taxation in developing countries has been reviewed by Burgess and Stern, 1993, and more recently by Besley and Persson, 2013. These motivate our theoretical approach, and our analysis builds on them by considering the consequences of institutional weaknesses in the domain of environmental policy. Early reviews of environmental quality and willingness to pay (factors that can drive environmental policy) in developing countries are provided by Greenstone and Jack, 2015. Empirical evidence supports, among other factors, the idea that political economy constraints and market failures like missing property rights play important roles in driving inefficient environmental outcomes in developing countries. For instance, Burgess et al., 2012 use evidence from Indonesia to show that higher competition among administrative jurisdictions in a decentralized economy can spur deforestation. Similarly, Sanford, 2021 shows, in a cross-country setting, that elections drive increased deforestation, which is explained by the tendency of politicians to prioritize short-term private benefits over long-term public goods when they face political challenges. Jayachandran, 2022 reviews recent micro-economic evidence characterizing the complex relationship between development and the environment. We contribute to this body of work by identifying economic mechanisms that can shape environmental outcomes even in the absence of explicit political economy forces.

This paper also contributes to an ongoing methodological discussion on environmental policy analysis. Fullerton and Heutel, 2007 consider the incidence of environmental taxes for different factors of production under general equilibrium, and Fullerton and Heutel, 2010 broaden the discussion by including other environmental mandates. While these works acknowledge the possibility of a pollution tax leading to more pollution, Garnache and Mérel, 2022 argue that these results are driven under equilibrium instability in a Marshallian manner, and they disappear when a different numeraire is chosen or an ad valorem tax is used instead of a specific tax. Our analysis diverges in several ways, including the focus on institutional factors, economic openness, and dynamic properties. Furthermore, we derive our results using ad valorem taxes–independent of the numeraire-choice problem. Finally, the modeling framework employed in this paper aligns with the literature on structural transformation, including Matsuyama, 2019, Matsuyama, 1992, and Nath, forthcoming. These papers characterize the role of trade restrictions in shaping domestic mechanisms that drive sectoral allocation of labor. Our paper builds on these mechanisms by analyzing the role of institutions (property rights and leakage), the environmental effectiveness of tax policies, and the response of optimal policies to natural shocks.

2 The benchmark model

We start with an infinite horizon economy that is closed (autarkic) and decentralized (DC henceforth). Following Matsuyama (1992), we consider two sectors: manufacturing and agriculture. The population of the economy under question is normalized to one, with the fraction of labor employed in manufacturing given by n. Production functions in the two sectors are given by

$$Y_t^M = MF(n_t) \tag{1}$$

$$Y_t^A = AG(T, 1 - n_t),\ G_i > 0,\ G_{ii} < 0,\ G_{ij} > 0,\ i, j = T, L,\ L \equiv 1 - n, \tag{2}$$

where manufacturing productivity, M, reflects knowledge capital and is given. T is a nature-based endowment (named land, for simplicity), and agricultural productivity, A, may reflect the level of technology and climate among other things. The functions F and G are strictly concave and they satisfy $F(0) = G(0, 0) = 0$.

Following the literature, we characterize the dynamics of the nature-based asset T as:

$$T_t - T_{t-1} = F(T_{t-1}) - Z_{t-1}, \tag{3}$$

where $F(T_t)$ denotes a net growth function (e.g., the difference between birth and mortality), and Z_t represents the period t harvest. The change in the current stock of the resource is given by the difference between growth and harvest. If harvests were to consistently exceed growth, the renewable resource would decline and vice versa.[1]

Importantly, we assume incomplete property rights in nature-based assets, thus individual agents do not internalize the resource constraint, which is a crucial feature of the model. This behavior introduces a dynamic distortion and gives rise to an outcome reminiscent of the "tragedy of the commons," in that the realized "harvest" level is higher than the social optimum discussed below. To put it differently, the absence of complete property rights in renewable resources leads to an over-allocation of labor in "agriculture" relative to the social optimum.

Labor is perfectly mobile between the two sectors and responds to (only) wage differentials so that

$$AG_L(T, 1 - n_t) = p_t M_t F'(n_t). \tag{4}$$

On the demand side, consumers have identical non-homothetic preferences given by

$$U = \sum_0^{\infty} \delta^t [\beta \ln(c_t^A - \gamma) + \ln c_t^M],\ \delta \epsilon (0, 1],\ \beta, \gamma > 0 \tag{5}$$

where c^A and c^M denote the consumption of the manufacturing good and the agricultural good (called food for brevity), δ represents the discount factor, while γ is the subsistence level of food consumption and satisfies

$$AG(T, 1) > \gamma > 0 \tag{6}$$

implying (i) that if all workers are employed in food production, they will be able to satisfy the subsistence needs of the population, and (ii) that with positive γ, preferences are non-homothetic and the income elasticity of demand for food is less than unitary. Further, we assume that all consumers have enough income, I_t, to consume more than γ units of food.

[1] Typically, the growth function $F(X_t)$ is modeled as dependent on an intrinsic growth rate, r, and a carrying capacity, K, with periods of rising and declining changes in the stock. A popular growth function is logistic, $F(X_t) = r(1 - X_t/K)$. In our simulations, we will use the growth function $F(X_t) = rX^{\alpha} - K$, $\alpha < 0$, $K > 0$ and the harvest function $Z_t = \varrho Y_t^a$.

Given the budget constraint, where p denotes the relative price of manufactures,

$$c_t^A + p_t c_t^M \leq I_t, \tag{7}$$

the static first-order conditions for utility maximization yield

$$c_t^A = \gamma + \beta p_t c_t^M, \tag{8}$$

with the solutions for consumption given by

$$c_t^A - \gamma = \frac{\beta(I_t - \gamma)}{1+\beta},\ p_t c_t^M = \frac{I_t - \gamma}{1+\beta}. \tag{9}$$

In a closed economy, demand for each good must equal its supply so that (given that population is normalized to one) $c_t^M = Y_t^M$ and $c_t^A = Y_t^A$. Thus we have

$$AG(T_t, 1-n_t) = \gamma + \beta p_t MF(n_t) \tag{10}$$

Using this with (4) yields

$$G(T, 1-n) - \beta G_L(T, 1-n)v(n) = \frac{\gamma}{A},\ v(n) \equiv \frac{F(n)}{F'(n)} > 0,\ v'(n) > 0, \tag{11}$$

which, in turn, solves for a unique labor allocation across sectors n_t such that $n_t = \varphi(T, A, \beta, \gamma)$ with

$$\varphi_T = \frac{n\omega_T(\sigma - \beta\varsigma)}{\Theta T},\ \varsigma \equiv \frac{pY^M}{Y^A} = \frac{Y^A - \gamma}{\beta Y^A},\ \varphi_A = \frac{n\gamma\sigma}{\Theta A Y^A} > 0,$$

$$\varphi_\beta = -\frac{n\varsigma\sigma}{\mathit{\Theta}} < 0,\ \varphi_\gamma = \frac{-n\sigma}{Y^a\Theta} < 0$$

$$\mathit{\Theta} \equiv \left[[n(1-n)^{-1}\omega_T + \sigma]\beta\varsigma + n(1-n)^{-1}\sigma\omega_L\right] > 0$$

$$\omega_T = \frac{dlnY^A}{dlnT},\ \omega_L = \frac{dlnY^A}{dlnL},$$

where σ denotes the elasticity of substitution between labor and land and ς is the value of manufacturing output relative to that of agriculture.

In this framework, a decrease in the land endowment have three effects on the allocation of labor, n. First, it reduces the marginal productivity of labor, MPL, in agriculture, lowering wages there and pushing labor towards manufactures, i.e., an increase in n. Second, the decrease in land lowers agricultural output, creating excess demand for the agricultural good, raising its relative price and decreasing the relative price, p, of the manufacturing good and pulling labor into agriculture. Third, with lower land, total income decreases, shifting demand composition in favor of the agricultural output and reinforcing the second effect. The net effect of a decrease in land endowment on agricultural employment thus depends on the relative strength of these three channels.

Figure 1: Goods and labor market equilibrium

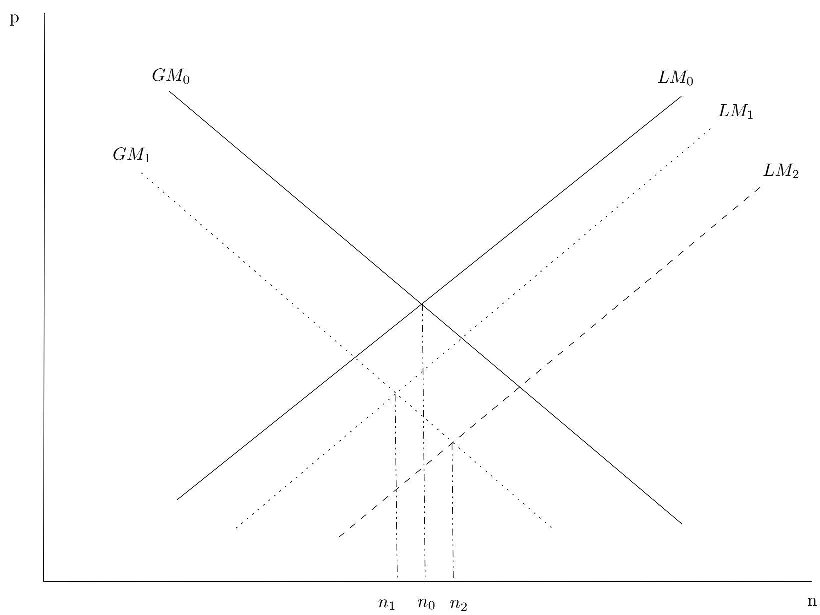


Figure (1) shows these mechanisms through the lens of goods and labor market equilibrium conditions. While the goods market equilibrium condition (Equation 10) is shown by the downward-sloping GM curve on the $p-n$ plane, the labor market equilibrium condition (Equation 4) is represented as the upward-sloping LM curve. Given an initial labor allocation n_0, a decrease in T lowers the supply of the agricultural good, decreases the relative price of manufactures, and shifts the GM curve down to GM_1. This fall in T reduces the marginal productivity of labor and the wage rate in agriculture, and, given p, shifts the LM curve to the right, increasing n. Though the effect of these shifts is to reduce p unambiguously, whether equilibrium n rises or falls depends on the relative magnitude of the shifts in GM and LM curves (indicated in the graph by the two LM curves, LM_1 and LM_2), dovetailing the ambiguity of the sign of φ_T above.

3 Environmental policy

The benchmark economy has so far considered weak property rights in renewable resources (i.e., land.), with the implication that in a decentralized setting, private agents do not internalize the resource constraint (3). In this section we introduce policies to alleviate the over-exploitation of natural resources. To do this, we start from the social planner's solution.

3.1 Socially optimal solution

The Social Planner (SP) maximizes the present discounted utility of the representative agent subject to the budget constraint (7) and the resource constraint (3). The Hamiltonian, $\mathbb{H}$, for this problem is

$$\mathbb{H} = \delta^t U(c_t^A, c_t^M) + \mu_{t+1}[F(T_t) - \varrho Y_t^a],\ \mu_{T+1} > 0$$

where μ_{t+1} denotes the shadow price of the renewable resource T_1. The first-order conditions yield, in addition to (8) and (3)

$$\mu_{t+1} = \frac{\delta^t}{p_t c_t^M} \frac{w_t^A - w_t^M}{w_t^A} \tag{12}$$

$$\mu_{t+1} - \mu_t = -\mu_{t+1}[\frac{w_t^M}{w_t^A - w_t^M} + F'(.)] \tag{13}$$

which, together with (3), yield the first-order difference equation

$$n_t = \varphi(n_{t-1}, T_{1t-1}) \tag{14}$$

One immediate implication of the first-order condition (12) that needs to be highlighted is that the SP allocates labor across the two sectors by taking into account the negative externality (or, the dynamic distortion) involved in "harvesting" decisions, so that it allocates less labor to agriculture than private agents would if property rights were imperfect:

$$w_t^{M,SP} < w_t^{A,SP} \Longleftrightarrow n_t^{SP} > n_t^{DC} \tag{15}$$

To derive the time paths of n_t and T_{1t} given by the difference equations (3) and (14), we start by replacing $p_t c_t^M$ with (9) and using the appropriate expressions for income in the cases of closed and open economies.[2] Next, we note that at a steady state $(\mu_{t+1} - \mu_t)/\mu_{t+1} = 1 - 1/\delta$ and setting $x_t = x_{t-1} = \bar{x}$ for $x = n, T_1$ derive the implicit expressions for the steady-state values of the variables, which we then use to linearize the two difference equations at hand. Simulation results by Karayalcin and Onder, 2023 show that, as expected, with one predetermined (T_1) and one jumping (n) variable the system is saddle-path stable. Further, regardless of the values of substitution elasticities ρ and σ, the stable arm of the saddle path slopes upward (downward) when the economy is closed (open) in the $n - T_1$ plane. With these solutions, we can next turn to our main problem in this paper.

3.2 Environmental taxes in a decentralized economy

Can policy makers implement the social planner's solution in a decentralized economy with incomplete property rights over nature-based assets? To answer this, we start by examining the implications of a proportional tax, τ, on "harvesting," that is on the production of the agricultural good, the profit maximization problem of the firms operating in that sector yields the first-order condition for employment as

$$(1 - \tau)AG_L = w^a. \tag{16}$$

In a decentralized setting with incomplete property rights, labor is perfectly mobile

[2]Note the contrast between the point-in-time equilibria of the social planner and the decentralized economy cases. In a decentralized economy with incomplete property rights, atomic agents do not internalize the constraint that dictates the time path of the renewable resource. As a consequence, they take the time path of the resource as parametric, making a sequence of static labor allocation decisions, which, in the aggregate, gives rise to a sequence of equilibria described in the section above.

between the two sectors so that

$$(1-\tau)AG_L(T, 1-n_t) = p_t M_t F'(n_t). \tag{17}$$

While the tax receipts are rebated lump-sum to households; a fraction, κ, of them can "leak out" of the economy, reflecting common institutional weaknesses in developing countries, e.g., tax evasion or corruption.

In a closed economy, demand for each good must equal its supply so that (given that population is normalized to one) $c^M = Y^M$ and $c^A = (1-\tau\kappa)Y^A$. Using these with the first-order condition for consumption and (17) yields

$$(1-\tau\kappa)AG(T, 1-n) - (1-\tau)\beta AG_L(T, 1-n)v(n) = \gamma, \tag{18}$$

which, in turn, solves for a unique n_t such that

$$n_t = \varphi(\tau, \kappa),\ \varphi_\tau = \frac{nY^A[(1-\kappa) - \gamma/Y^A]}{(1-\tau)\Theta} \lesseqgtr 0,\ \varphi_\kappa = \frac{-\tau Y^A}{\Theta},\ \Theta > 0. \tag{19}$$

When $\kappa = 1$, $\varphi_\tau = -n\gamma/(1-\tau)\Theta < 0$, implying that a higher tax increases agricultural employment and output, defeating the purpose of the tax. However, if $\kappa = 0$, increasing the tax rate τ moves labor out of agriculture as in the standard case. By continuity, there is a critical level, denoted by κ^*, at which $\varphi_\tau = 0$. We summarize this result as follows.

Result 1 (The environmental impact of environmental taxes) *In a closed economy with incomplete property rights over nature-based assets, there exists a threshold level of institutional quality (efficiency in tax collection) above which a tax on the nature-based asset can slow its harvesting. By contrast, for lower levels of institutional quality, the same tax can be self-defeating by accelerating harvesting.*

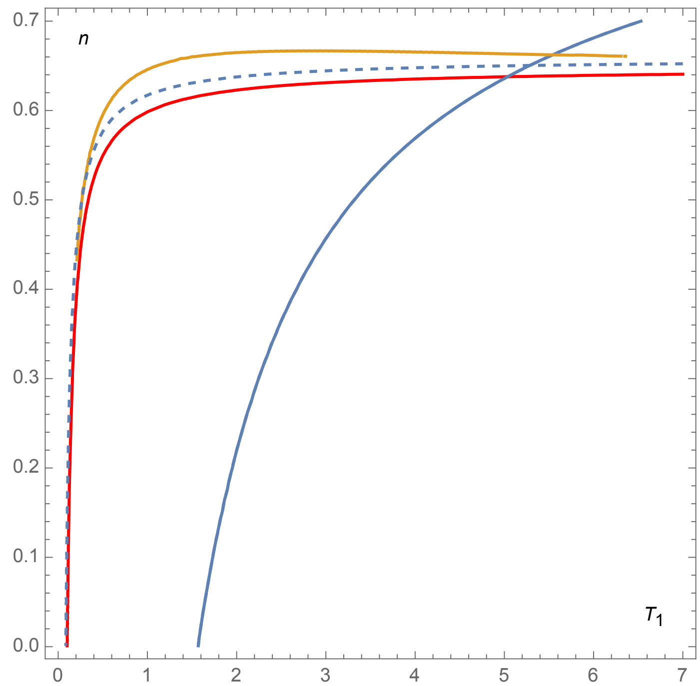
Intuitively, if enough of the agricultural tax collected "leaks out" of the economy, lower food availability and higher relative demand for food would increase relative food prices and attract more labor to agriculture. To visualize this, refer once more to Figure (1), where the tax on agricultural output lowers, depending on the extent of the "leakage," the supply of food, shifting the GM curve down, decreasing, ceteris paribus, the relative price of manufactures and n. The tax also shifts the LM curve down by reducing the marginal productivity of labor and the wage rate in agriculture, increasing n. Whether equilibrium n rises or falls depends on the relative magnitudes of these shifts, reflecting the ambiguity φ_τ in equation (19).

A positive relationship between agricultural employment and agricultural taxes also implies that the policy required to deal with the negative externality would be to subsidize agricultural production[3]. To see how such a policy would work, it is best to begin with a steady-state equilibrium in the closed economy. Figure 2 depicts the effects of such a subsidy on the steady-state allocation of labor, n. In the figure, we illustrate the joint steady-state determination of n and T_1 in both the DC (with and without taxes) and SP cases. For this, we use (i) the equation describing the time path of renewable resources, (3) (blue curve),[4]

[3]Jack et al., forthcoming demonstrate the effectiveness of a subsidy in addressing a negative externality.

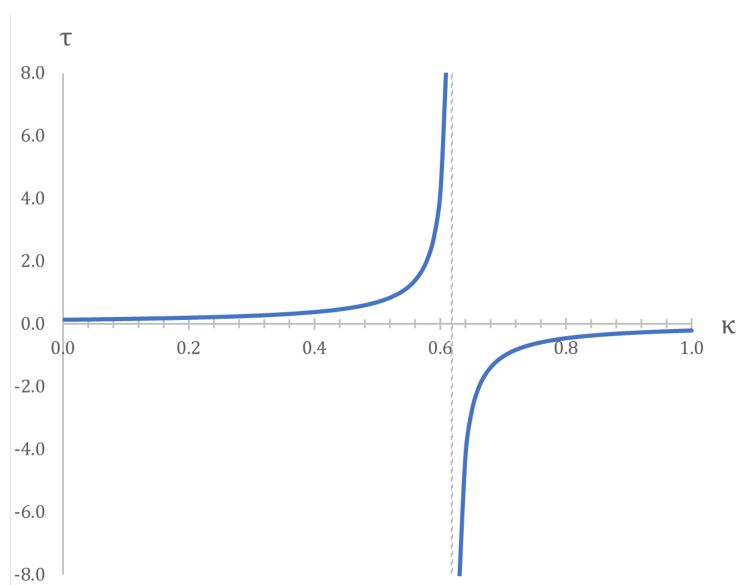
[4]Note that this equation holds in both the DC and SP cases and is not affected by taxes/subsidies.

Figure 2: The effect of a subsidy at steady state



Notes: Figure shows the effects of a subsidy on the steady-state allocation of labor, n. Curves depict the following: (i) Blue: the equation describing the time path of renewable resources (equation 3), (ii) Red: the equation (18) for DC, and (iii) Yellow: equations (12 and (13) with $\mu_{t+1} = \mu_t$ for SP.

Figure 3: Steady-state tax/subsidy levels as a function of κ



Notes: Figure shows the level of optimal taxes/subsidies (τ) as a function of the leakage parameter (κ), using the following parameter values: $\beta = 0.3$, $\sigma = 0.8$, $\rho = 0.5$.

(ii) equation (18) for DC (red curve), and (iii) equations (12) and (13) with $\mu_{t+1} = \mu_t$ for SP (yellow curve). The levels of both n and T_1 in the SP case (given by the intersection of the blue and yellow curves) exceed those of the DC solution (given by the intersection of the red and blue curves). For a high enough κ (in the figure $\kappa = 1$) a subsidy to food production shifts the red curve upwards (to the dashed curve), moving labor out of agriculture and getting an equilibrium labor allocation closer to the optimal. In contrast, the standard remedy of a tax on agricultural output would result in a downward shift (not shown) of the red curve and increase labor employed in agriculture.

It is useful also to understand how an optimal steady-state tax/subsidy depends on the "leakage" parameter κ. Simulations shown in Figure (3) depict the optimal tax (subsidy) in a closed economy rising (falling) as κ increases. The intuition behind these results can be understood with reference to equation (19), which shows n falling (rising) with κ when τ is positive (negative). Thus, when the optimal policy is to impose a tax on agricultural output, higher levels of "leakage" reduce food supply, increase its relative price and agricultural wages, and allocate more labor to agriculture. To counteract this decline in n, higher taxes to lower agricultural wages are called for. On the other hand, when the optimal policy is a subsidy, more "leakage" κ increases employment in manufactures, n, by increasing the supply of the agricultural good and lowering its relative price. An immediate consequence of this is the reduction in the optimal subsidy.

4 Extensions

Having obtained our main result, we next analyze the validity of this result under various conditions, including with different elasticities of land-labor substitution in agriculture, different subsistence food consumption levels, different trade regimes, and under inequality of income among consumers. In addition, we characterize the dynamic profile of environmental taxation in the wake of natural shocks and discuss the implications of international transfers for the main result of this paper.

4.1 The role of factor substitution in agriculture

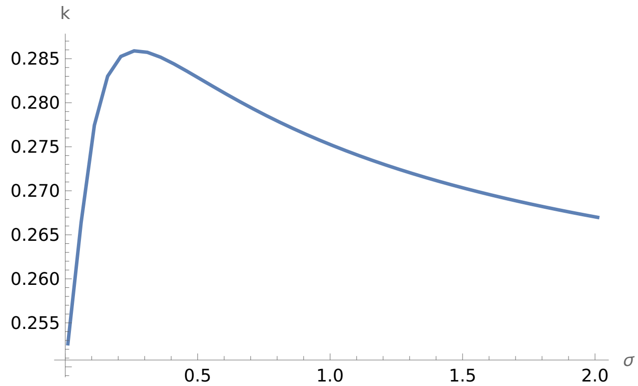
Does the production technology in agriculture drive the environmental impact of environmental taxes? To investigate this, we consider a Constant Elasticity of Substitution (CES) production function as follows:

$$Y^a = A\left[(1-\theta)T^{\xi} + \theta(1-n)^{\xi}\right]^{1/\xi} \equiv A\Omega^{1/\xi}$$

with $\xi \in (-\infty, 1]$, and the elasticity of substitution is given by $\sigma = 1/(1-\xi)$. Thus, when $\xi \to 1$ the inputs are perfect substitutes, and when $\xi \to -\infty$, they are perfect complements (the Leontief case), with $\xi = 0$ yielding the Cobb-Douglas case.

Given this CES production function in agriculture, we can now investigate how the elasticity of input substitution in agriculture can influence the relationship between the environmental taxes and employment in agriculture. More specifically, we are interested in assessing if different values of this elasticity can weaken or reinforce the paradoxical result described earlier. However, without a tractable analytical solution, we use numerical simulations to do this. Figure (4) shows the results. When land and labor are strong

Figure 4: The effect of σ on the threshold level of leakage, κ^*



Notes: Figure shows the critical value of the leakage parameter (κ^*) described in equation (19) as a function of the input elasticity in agriculture (σ).

complements (low σ values), a small increase in σ increases the threshold value of κ, weakening the paradoxical result by increasing the required leakage for it to hold. In contrast, when land and labor are weakly complementary or substitutes, then a higher σ reduces the threshold κ, reinforcing the paradoxical result. We summarize these findings in the following result.

Result 2 (Factor substitution and the paradoxical result) *In a closed economy with incomplete property rights over nature-based assets, there exists a non-monotonic relationship between the elasticity of input (land-labor) substitution in agriculture (σ) and the threshold level of leakage (κ^*) beyond which environmental taxes can become self-defeating.*

To interpret this result, we need to consider two factors. First, notice that in a structural transformation model, a higher elasticity of factor substitution in a given sector can help that sector more easily substitute away from more expensive inputs compared to a low elasticity case, as shown by Alvarez-Cuadrado et al., 2017. In our framework, for given levels of tax and leakage, this effect reinforces the paradoxical result because the labor outflow from agriculture will be weakened with higher elasticity of substitution when a tax reduces the marginal productivity of labor and wages. Second, a higher elasticity of substitution also increases the agricultural output and total income. These, in turn, work against our paradoxical result as the relative price channel is weakened with greater food supply and a more manufacturing-oriented composition of aggregate demand that comes with higher incomes. It turns out that which of these factors dominate changes over the σ spectrum: for lower levels of σ, the latter effect dominates and the paradoxical result becomes less likely when σ increases (higher κ^*), and for higher levels, the opposite holds true.

4.2 The role of demand composition

The income elasticity of demand for the agricultural good plays an important role in driving our main result. With a non-homothetic utility, where a minimum consumption requirement (γ) sets the demand elasticity for food less than unitary, changes in aggregate income have both scale effects (aggregate demand) and composition effects (relative demand). The latter proves to be consequential for our analysis.

To see the role played by γ, recall the equation (19):

$$n_t = \varphi(\tau, \kappa), \ \varphi_\tau = \frac{nY^A[(1-\kappa) - \gamma/Y^A]}{(1-\tau)\Theta} \lesseqgtr 0, \ \varphi_\kappa = \frac{-\tau Y^A}{\Theta}, \ \Theta > 0.$$

Note that if $\gamma = 0$ an increase in τ would always increase n as in the standard case. On the other hand, if $\kappa = 1$, an increase in τ would always decrease n. Intuitively, with positive leakage, the tax on the nature-based asset reduces the demand for agricultural good through the scale effect, but increases it through the composition effect. That is, with lower income, relative demand for the agricultural increases as a result of the less than unitary income elasticity of demand, which reinforces the case of a self-defeating environmental tax.

4.3 The role of international trade

We now consider the open economy case. Suppose that the economy we discussed above, in the benchmark case, is a small open economy in that, it is small enough that changes in its supply or demand for the two goods it consumes and produces will not affect the relative price of manufactures, p^* in the rest of the world, so that $p = p^*$. Assuming further that there is no international movement of labor, equation (4) will solve for

$$n_t = n(T, A; M, p^*), \ n_T = \frac{AG_{LT}}{\Pi} < 0, \ n_{p^*} = \frac{A}{p^* M \Pi} > 0,$$

where $\Pi \equiv p^* M F''(n_t) + G_{LL} < 0$. If we also assume that there is no international borrowing, $Y = E$ and

$$Y = \tilde{Y}(T, A; p), \ \tilde{Y}_T = AG_T > 0, \ \tilde{Y}_p = MF(n) > 0 \tag{20}$$

as $dY/dn = 0$ from the envelope theorem.

Note that a key difference between a closed and open economy is in how they propagate a natural shock. Consider the shock in the Home economy. When the economy is closed, a tax on agricultural output τ has two opposing effects on n (the amount of labor in manufacturing production). First, by reducing the marginal revenue product of labor in agriculture, it reduces agricultural wages, thereby raising n. Second, the decline in the supply of the agricultural good, along with the demand composition effect that comes with the decrease in income, raises its price, and thus reduces the relative price of manufactures and the marginal revenue product of labor employed in that sector, lowering wages there. This leads to a decline in n. In the simulations for the benchmark model, the net effect on n depends on the leakage parameter κ. When $\kappa > \kappa^*$, the second channel dominates, and n decreases. In the open economy case, with prices given by the rest of the world, such a price effect is absent. Consequently, n rises after the natural shock. We next analyze the implications of this difference for fragility and resilience in the two trade regimes.

Given our discussion of the mechanisms involved in how κ affects optimal taxes in closed economies, it should be clear by now that "leakages" cannot play a role in the determination of such taxes in open economies. Intuitively, in a small open economy, changes in the supply of the agricultural good do not, by definition, affect relative prices and, via these, relative remuneration of labor. Thus, the only channel through which taxes influence labor allocation decisions is the direct one formalized in equation (17): a higher tax on "harvesting", i.e. the output of the agricultural good, reduces wages in agriculture and reallocates labor to manufacturing as desired.

4.4 The role of international transfers

The next question we analyze is the impact of international transfers. Suppose the country in consideration receives a unilateral windfall transfer (received by the representative agent), how would that affect the environmental outcomes in our benchmark case with an otherwise closed and decentralized economy?

Given the two-sector format of the model, the transfer would need to be in kind, either food, s^A or manufactures, s^M, or a mix of the two, such that we have: (1) the quantity of food increased to Y^A+s^A, (2) the quantity of manufactures available to consumers raised to $Y^M + s^M$, or (3) both quantities increase at an arbitrary proportion with a transfer bundle $\{s^A, s^M\}$. Analytically, it is straightforward to show that in the first case, employment in manufacturing n rises, yielding the desired result for the correction of the dynamic externality, and in the second case n falls, increasing harvesting and environmental degradation. To see this, note that we have for GM the following equation with transfers of food, s^A, and manufactures, s^M

$$\texttt{GM} : c^A - \gamma = \beta p c^M \iff (1-\tau\kappa)[AG(T, 1-n) + s^A] - \gamma = \beta p[MF(n) + s^M]$$

or

$$(1-\tau\kappa)[AG(T, 1-n)] - \gamma = \beta p[MF(n)] + [\beta p s^M - (1-\tau\kappa)s^A].$$

For a given T, we can consider these cases as the transfer s^A shifting the GM locus to the right in Figure (1), while the transfer s^M does the opposite. Now, to see the third case–a bundle with both goods, note that if the last expression on the right-hand side equals zero, that is if

$$\beta p s^M = (1-\tau\kappa)s^A, \tag{21}$$

we get the same GM and, thus, the same $\{n, p\}$ as the case where there are no international transfers. So the bundle $\{s^A, s^M\}$ that satisfies equation (21) is the one that has no effect on the labor allocation, n. Donating an s^A that is slightly higher than this will increase n and reduce "harvesting" and help reduce the distortion.

4.5 The role of inequality

Our analysis has so far abstracted from distributional concerns by utilizing a representative agent framework. It is, however, worth considering how income inequality might affect our results as environmental tax proceeds or international transfers may be captured by the elites. In our benchmark specification, these are inconsequential because, with non-homothetic preferences and a subsistence level of consumption in agriculture, income distribution does not affect aggregate demand as long as income is high enough to generate positive demand for the agricultural output. To consider a case where inequality in income can affect aggregate demand, we follow Markusen, 2013 and Behzadan et al., 2017 and consider the following Stone-Geary variant for consumer preferences:

$$U = \sum_{0}^{\infty} \delta^t [\beta \ln(c_t^A) + \ln(c_t^M + \mu)],\ \delta\epsilon(0,1],\ \beta, \mu > 0, \tag{22}$$

where μ denotes the consumption of an endowment good that is not sold or purchased by households. With $\mu > 0$ satisfied, c^M becomes a luxury good that is not purchased when income is low, allowing income distribution to play a role.

Next, to analyze the effect of income inequality for our results, consider a mean-preserving spread, with ϵ deduction from each $m \in [0,1]$ households (who become the "poor" after the deduction and denote their consumption choices with subscript 1) and an addition for $(1-m)$ households (the "rich", with subscript 2), yielding $\epsilon[m/(1-m)]$ for each recipient.[5] Given this structure, the consumption of goods by each type of consumer is given by:

$$c_1^A = \min\left\{ I_t - \epsilon, \frac{\beta\,(I_t - \epsilon) + \beta p \mu}{1+\beta} \right\},\quad c_1^M = \max\left\{ 0, \frac{(I_t - \epsilon) - \beta p \mu}{p(1+\beta)} \right\} \tag{23}$$

$$c_2^A = \min\left\{ I_t + \frac{\epsilon m}{1-m}, \frac{\beta\left[I_t + \frac{\epsilon m}{1-m}\right] + \beta p \mu}{1+\beta} \right\},\quad c_2^M = \max\left\{ 0, \frac{\left[I_t + \frac{\epsilon m}{1-m}\right] - \beta p \mu}{p(1+\beta)} \right\}. \tag{24}$$

There are three cases of interest: (i) For $I_t > \epsilon + \beta p \mu$, both groups have sufficiently high incomes to purchase c^M, with positive aggregate demand for c^M, and a relatively small change in income distribution does not affect this demand; (ii) for $I_t < \beta p \mu - \epsilon[m/(1-m)]$, neither group can afford c^M, and a small change in income distribution does not change this outcome; (iii) for $\beta p \mu - \epsilon[m/(1-m)] < I_t < \epsilon + \beta p \mu$, only the rich can afford to buy c^M, and a redistribution from the poor to the rich increases the aggregate demand for c^M. Therefore, we use this third scenario where $c_1^M = 0$ and $c_2^M > 0$ to analyze the implications of income inequality for our main results.

Total consumption of goods $c^A = mc_1^A + (1-m)c_2^A$ and $c^M = mc_1^M + (1-m)c_2^M$ when manufacturing is only consumed by the rich are given by:

$$c^A = \frac{(m+\beta)I_t + (1-m)p\beta\mu - m\epsilon}{1+\beta}, \tag{25}$$

$$c^M = \frac{(1-m)I_t - (1-m)p\beta\mu + m\epsilon}{p(1+\beta)}. \tag{26}$$

which yields the following relationship:

$$c^A = \frac{p(m+\beta)}{(1-m)} c^M - \frac{m\epsilon}{(1-m)} + p\beta\mu. \tag{27}$$

[5]This can be interpreted as the outcome of a regressive policy, such as fuel subsidies, whose benefits are captured largely by higher income groups. For more discussion on this, see Clements et al., 2015

Considering $c^M = Y^M$ and $c^A = (1-\tau\kappa)Y^A$ and incorporating the labor mobility condition 17, we receive the following equilibrium condition which clears both the goods and labor markets:

$$(1-\tau\kappa)AG(T,1-n) - (1-\tau)\left(\frac{m+\beta}{1-m}\right)AG_L(T,1-n)v(n) \\ -(1-\tau)\beta\mu\left(\frac{AG_L(T,1-n)}{MF'(n_t)}\right) = -\frac{m\epsilon}{(1-m)} \tag{28}$$

We are interested in how a reduction in inequality could change the paradoxical result, i.e., whether it weakens the unintended increase in agricultural employment as a result of the environmental tax or not. To see this, we introduce an arbitrary reduction in the spread, which becomes $\epsilon - e$. Next, by using the equation (28), we can observe the effect of the environmental tax τ on manufacturing employment n in this case with inequality as follows:

$$\frac{\partial n}{\partial \tau} < 0 \quad if \quad \frac{(1-\tau\kappa)AG(T,1-n) + m(\epsilon - e)/(1-m)}{(1-\tau)AG(T,1-n)} < \kappa. \tag{29}$$

This shows that, ceteris paribus, a small progressive redistribution depicted by e, which reduces the mean-preserving spread ϵ, can reinforce the paradoxical effect of the environmental taxes in agriculture, $\partial n/\partial\tau < 0$. We summarize this finding in the following result.

Result 3 (The role of inequality) *Consider a closed economy with incomplete property rights over land and non-homothetic preferences (manufacturing is a luxury good). Ceteris paribus, a small redistribution to reduce income inequality (characterized by a mean-preserving spread) can reinforce the harvest-increasing effect of a tax on the nature-based asset.*

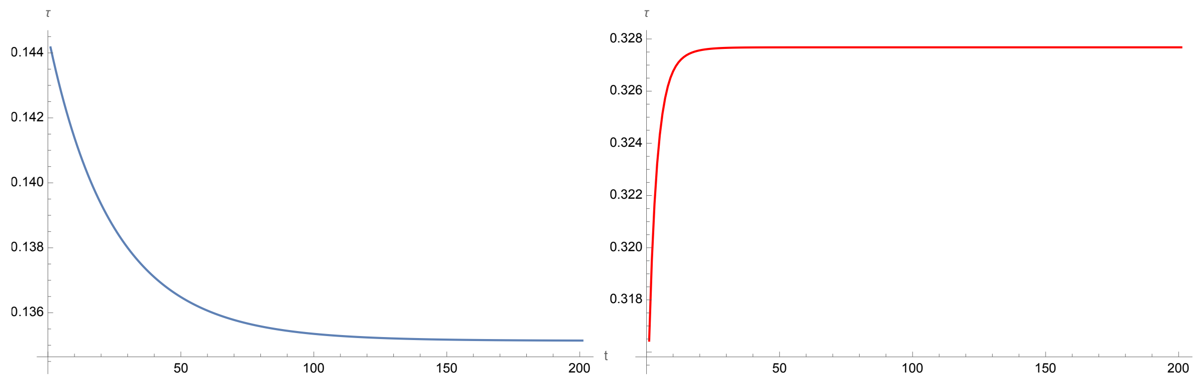
Recall that when leakage reduces aggregate income in the presence of weak institutions, it increases the demand for the agricultural good under non-homothetic preferences, leading to the paradoxical result. The crucial point here is that income inequality weakens this demand composition effect. To see this, consider an identical group of consumers who are rich enough to afford the manufacturing good. In this case, when leakage reduces aggregate income, everybody will spend a greater share of their income on the agricultural good. In contrast, when only a subgroup of the consumers are rich enough to purchase the manufacturing good, leakage will shift demand from manufacturing to agriculture only for this group, reducing the magnitude of the demand composition effect that drives the harvest-increasing effect of the tax. Finally, when income redistribution reduces inequality, thus, it also makes it more likely that the agricultural tax boosts agricultural employment, further reducing the natural assets – the paradoxical result.

4.6 Tax/subsidy response to natural shocks

In our final extension, we examine the dynamic properties of the optimal taxes/subsidies as the economy responds to a land-reducing climate shock. The simulations we run assume that, in response to the shock that buffets the economy at the beginning of period 0, policy makers adopt an optimal tax/subsidy that attains the labor allocation that would have been

Figure 5: Optimal taxes in closed and open economies

(a) Closed economy (b) Open economy



Notes: Figures show the adjustment of optimal taxes to a negative climate shock in closed and open economies. Parameter values are $\kappa = 0$, $\beta = 0.3$, $\sigma = 0.8$, and $\rho = 0.5$.

chosen by a social planner and, as a result, the same level of the renewable resource in the next period. We observe the following results.

Result 4 (Dynamics of taxes and subsidies) *Consider a "land-reducing" climate shock in a decentralized economy. The optimal taxes/subsidies in this economy has the following characteristics:*

1. *Before the shock, optimal taxes are higher if the economy is open and it has a comparative advantage in agriculture.*

2. *After the shock, optimal taxes can move in opposite directions in open and closed economies, increasing in the former case while decreasing in the latter.*

3. *When the optimal policy is a subsidy (only in closed economies), the shock can increase the optimal subsidies on impact.*

Intuitively, the first result is directly derived from the observation that an open economy with comparative advantage in agriculture allocates a greater share of its labor force to that sector compared to a closed economy. Consequently, higher taxes are required to move labor out of agriculture. The second result is based on the observation that in a small open economy, when the adverse shock reduces the natural resource T, the marginal product of labor and the agricultural wage, w^A decline, which decreases labor allocated to agriculture, thereby reducing the optimal tax. In contrast, in a closed economy, the reduction in T decreases the supply of the agricultural good, pushing up its relative price, and reducing w^M and employment in manufactures. If this channel dominates (as in Figure (5)), optimal taxes may increase. If the optimal policy involves a subsidy under these conditions (as noted in the third result), the shock can increase the optimal subsidy for the same reasons.

5 Conclusion

This paper analyzes the effectiveness of environmental policies under weak institutions, such as weak property rights over nature based assets and leakage from tax receipts–either due to corruption or costly tax collection efforts. Our results show, in a seemingly paradoxical way, that a tax levied to alleviate the over-exploitation can be self-defeating in a closed economy, i.e., it can increase the exploitation of the natural resource when the leakage is sufficiently large. The economic mechanisms that drive this result are unambiguous. While the tax reduces the marginal product of labor in agriculture, pushing it away from the sector, it also reduces the supply of food, increasing the food price. Furthermore, with non-homothetic preferences, leakage from the tax receipts shrinks total income, thereby shifting demand composition in favor of the agricultural good, further increasing its price. Taken together, the tax can drive an increase in agricultural employment and intensify harvest pressure on natural resources.

Our analysis also has clear policy implications. Most importantly, it shows the importance of designing environmental policies within a country's broader development context, not in isolation. Income growth and better institutions allow more effective environmental policies. Extensions to our benchmark analysis shows that the self-defeating character of environmental taxes can also be weakened through higher elasticity of substitution between the natural asset and labor in agriculture, economic openness, and international transfers comprising a relatively large share of the agricultural good.

References

Alvarez-Cuadrado, F., Van Long, N., & Poschke, M. (2017). Capital–labor substitution, structural change, and growth. *Theoretical Economics*, *12*(3), 1229–1266.

Andersen, J. J., Johannesen, N., Lassen, D. D., & Paltseva, E. (2017). Petro rents, political institutions, and hidden wealth: Evidence from offshore bank accounts. *Journal of the European Economic Association*, *15*(4), 818–860.

Andersen, J. J., Johannesen, N., & Rijkers, B. (2022). Elite capture of foreign aid: Evidence from offshore bank accounts. *Journal of Political Economy*, *130*(2), 388–425.

Behzadan, N., Chisik, R., Onder, H., & Battaile, B. (2017). Does inequality drive the dutch disease? theory and evidence. *Journal of International Economics*, *106*, 104–118.

Besley, T., & Persson, T. (2013). Taxation and development. In *Handbook of public economics* (pp. 51–110). Elsevier.

Burgess, R., Hansen, M., Olken, B. A., Potapov, P., & Sieber, S. (2012). The political economy of deforestation in the tropics. *The Quarterly Journal of Economics*, *127*(4), 1707–1754.

Burgess, R., & Stern, N. H. (1993). Taxation and development. *Journal of Economic Literature*, *31*(2), 762–830.

Clements, M. B. J., de Mooij, R. A., Gupta, M. S., & Keen, M. M. (2015). *Inequality and fiscal policy*. International Monetary Fund.

Fullerton, D., & Heutel, G. (2007). The general equilibrium incidence of environmental taxes. *Journal of Public Economics*, *91*(3-4), 571–591.

Fullerton, D., & Heutel, G. (2010). The general equilibrium incidence of environmental mandates. *American Economic Journal: Economic Policy*, *2*(3), 64–89.

Garnache, C., & Mérel, P. (2022). Environmental policy in general equilibrium: New insights from a canonical model. *Journal of the Association of Environmental and Resource Economists*, *9*(1), 113–140.

Greenstone, M., & Jack, B. K. (2015). Envirodevonomics: A research agenda for an emerging field. *Journal of Economic Literature*, *53*(1), 5–42.

Jack, B. K., Jayachandran, S., Kala, N., & Pande, R. (forthcoming). Money (not) to burn: Payments for ecosystem services to reduce crop residue burning. *American Economic Review: Insights*.

Jayachandran, S. (2022). How economic development influences the environment. *Annual Review of Economics*, *14*, 229–252.

Karayalcin, C., & Onder, H. (2023). *The Fragility and Resilience of Nations* (Policy Research Working Paper Series No. 10362). The World Bank.

Markusen, J. R. (2013). Putting per-capita income back into trade theory. *Journal of International Economics*, *90*(2), 255–265.

Matsuyama, K. (1992). Agricultural productivity, comparative advantage, and economic growth. *Journal of Economic Theory*, *58*(2), 317–334.

Matsuyama, K. (2019). Engel's law in the global economy: Demand-induced patterns of structural change, innovation, and trade. *Econometrica*, *87*(2), 497–528.

Nath, I. (forthcoming). Climate change, the food problem, and the challenge of adaptation through sectoral reallocation. *Journal of Political Economy*.

Olken, B. A., & Pande, R. (2012). Corruption in developing countries. *Annu. Rev. Econ.*, *4*(1), 479–509.

Sanford, L. (2021). Democratization, elections, and public goods: The evidence from deforestation. *American Journal of Political Science*.