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INTERNATIONAL TRADE AND THE INTERNALIZATION OF ENVIRONMENTAL DAMAGES

by

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with

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Abstract

This paper contributes to the growing effort to synthesize the fields of trade policy and environmental policy. We discuss: the question of whether international trade undercuts unilateral internalization policies; the role of income constraints in environmental policy; and the possibility of using trade policy to achieve environmental objectives. We review estimates of environmental damage in agricultural production and processing, and we summarize current policy measures. We use a static empirical model to estimate the effects of several internalization policies. We show how a dynamic model can be used to simulate the effects of policy over time, for both environmental and economic variables.

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1. Introduction

For the past several decades, the liberalization of world trade has been a central policy objective in international negotiations. Liberalization involves the formulation of and adherence to international rules which frequently require that domestic laws be modified. In the past decade it has become widely accepted that there is also an important global dimension to environmental problems, some of which require international coordination. At the same time, there has arisen concern that the goals of trade liberalization and environmental protection may conflict. As a result of this concern, considerable research has been devoted to understanding the relation between trade and the environment. This report is intended to contribute to that effort. The four principal chapters address different aspects of the trade-environment connection. The unifying goal is to understand better how international trade affects governments' ability to remedy environmental problems.

Our focus is on environmental damage caused by agricultural production and processing. It is difficult to monitor the actions of tens of thousands of farmers, or to measure the amount of damage they cause, making it difficult to control their behavior directly by means of standards. However, indirect measures, such as taxes and subsidies can be used to alter the relative prices that producers face, thus causing private and social relative costs to converge. If these taxes/subsidies are set properly, producers "internalize" the social costs of their decisions, i.e., they behave as if they were bearing those costs. We would like to know how international trade alters the efficacy of internalization policies for agriculture.

Some environmental problems have immediate and obvious international repercussions. The solutions to these transnational problems require international agreement. Examples include fishing from common stocks and the creation of pollution that leads to acid rain. We have not attempted to address these issues. We focus instead on production and processing that directly damages the local or national environment, e.g. water pollution or soil erosion. Many of these local problems also have an international dimension. For example, increasing the area planted to crops may involve deforestation, which leads directly to soil erosion, and also contributes to the greenhouse effect. In these cases, the agricultural activity creates both a global and a national social cost. A national government may have an incentive to correct the national but not the global externality. Where this occurs, there is a transnational problem, just as in the fishing and acid rain example. There are three reasons for our focus on national, rather than transnational environmental problems. The first is a practical consideration: by restricting our enquiry, our objective becomes more manageable. Second, more significant than the global ones. Third, the analysis of transnational externalities is in many respects similar to the analysis of national problems. There are differences between the two, since with transnational damages the jurisdiction of those who make the rules differs from the location of those who bear (some of) the costs. Therefore, the measurement of costs and the development of internalization policies also differ for national and transnational environmental problems. However the relation between international trade and each problem is similar. In both cases, trade might ameliorate or exacerbate the environmental problem.

The basic relation between international trade and the environment is straightforward. Environmental damage is associated with production (including processing) and/or consumption of commodities. International trade alters production and consumption, thus affecting the environment. Just as commodities embody labor and capital, they also embody various environmental factors. Trade in commodities is implicitly trade in environmental factors.

Even if environmental damages are exclusively national, so that the costs of using the environmental factors do not cross boundaries, some benefits (economic surplus) accrue to trading partners. Externalities result in inefficiencies, but the magnitude of these is usually dwarfed by the redistribution of income or wealth. In a closed economy, this redistribution involves citizens of the same country. If other tax policies are used to offset the distributional effects of the externality, so that externality may be of limited national importance. In an open economy, however, the redistribution involves trading partners. The fact that one agent gains and another looses, takes on special significance when the agents are citizens of different countries. International trade may therefore greatly increase the importance, to a nation, of existing externalities. International trade also enlarges the set of instruments available to governments, thereby increasing the complexity of policy decisions. Autarky remains an option, although seldom an attractive one.

Chapter 2 discusses several general aspects of the relation between internalization policies and international trade. First, we consider the argument that trade makes unilateral domestic internalization policies more difficult to implement and less effective. It makes them more difficult to implement, supposedly, because these policies raise domestic costs and result in a loss of market share. Because nations are unable to afford this loss of competitiveness, internalization policies require concerted multinational actions, so that all producers face the same cost increases. Trade makes unilateral internalization less effective, supposedly, because it shifts pollution, along with market share, to other countries. These arguments contain enough truth to make them dangerous, but we think that in large part they are an excuse for domestic inaction.

Next we consider to what extent the lessons learned from applying internalization policies in developed countries (DCs), are useful in less developed countries (LDCs). Part of the reason that poor farmers use environmentally damaging methods is that they are unable to afford to take a longer view, which would encourage conservation. Forcing them to bear the social cost of their actions would worsen their poverty, and might induce them to increase the damage to the environment. The income effects of internalization policies have to be taken seriously in LDCs. Borrowing concepts from modern industrial organization theory, we explain why, in the presence of income constraints, international trade can reinforce rather than undercut incentives for unilateral internalization policies.

Environmentalists and economists have different views regarding the merit of using trade policy to achieve environmental targets. Both views have theoretical support. We evaluate the two positions, with special attention to a recent proposal to create International Commodity Related Environmental Agreements.

Chapter 3 provides an overview of environmental damages and internalization policies (primarily) in LDCs. We review an empirical and an institutional literature. The empirical literature measures environmental damages related to agriculture; our review summarizes the type of information that is available. Economists are accustomed to working with abstract models, which involve concepts such as "damage functions". These concepts are useful for discussing general issues, but it is difficult to give them the precise empirical content needed for policy analysis. Economists need to know much more than "stylized facts" if they are to move beyond generalities. The information assembled in Chapter 3 will, we hope, make it easier for economists to acquire this information. The last part of the chapter discusses internalization policies that have been proposed and those which are currently being used. In DCs, environmental policy is inadequate, often contradictory, and sometimes counterproductive. Environmental policy is at an earlier stage in LDCs.

Chapter 4 illustrates one way in which trade economists can assist in the formulation of internalization policy. The obvious question to ask of trade economists is "How will domestic or multilateral internalization policies alter production and trade flows, market share, and trade balances?" This question involves issues which are familiar to model-builders who have worked on the question of trade liberalization or market reform. For both types of issues we want to know how government taxes and subsidies, or reforms which alter supply/demand relations, will change the market equilibrium. There are a number of trade models available to address these questions. We use the SWOPSIM model, developed by ERS-USDA, to examine the effect of taxes in a model of three commodities (coffee, sugar and cotton) and one input (fertilizer). We consider both unilateral and multilateral taxes, for both the input and the products. The fertilizer tax can be interpreted as a direct tax which causes farmers to internalize the environmental costs of the pollution that results from fertilizer use. The commodity taxes can be interpreted as implicit taxes. For example, a ban on certain pesticides might increase production costs. In that case, the output tax is interpreted as the "tax equivalent" of the ban.

First, the chapter describes the coffee, sugar and cotton markets. This background gives the reader a context in which to judge how well the model captures the complexities of the actual markets. The next section reviews the empirical literature on the three commodities. This review shows how uncertain we are regarding key parameters of the model, despite the accumulation of years of empirical research. The final section describes the SWOPSIM model and presents the simulation results. This chapter illustrates the ability - and the limitations—of international trade models in providing quantitative answers to the type of questions important to policymakers.

Chapter 5 studies a theoretical model which describes the dynamics of the relation between trade and the environment. We use this model to show how internalization policies alter the time path of trade flows, prices, and the environmental stock. The partial equilibrium model consists of two producing countries in the South and one consuming country in the North. Production of the commodity requires labor, an environmental stock, and inputs which damage the environmental stock. The environment can be protected by making investments; these do not alter current production, but change the future environmental stock, and thus change future supply. We consider the effect of input taxes and of a change in the nature of property rights which induces producers to internalize (a greater portion of) environmental costs. The environmental stock is an explicit variable in this model, unlike in the static model used in Chapter 4. We show analytically how changes in parameters alter the equilibrium within a period, and then report the results of numerical analysis which examines dynamic effects. We provide examples which illustrate why, in a dynamic setting, international trade may induce an exporter to imitate, rather than undercut (as in a static setting) a rival's internalization policies. We also show how the distribution of surplus, and the time path of this distribution, changes as a result of internalization policies. We then explain how the model can be estimated.

Each chapter is, to a large degree, self-contained. All chapters contain an introductory and a concluding section, and are followed by references.

2. Environmental Policies, Trade, and Income Effects

2.1 Introduction

This chapter discusses several issues that are important to the relation between international trade and the internalization of environmental externalities. A popular view is that free trade is inimical to domestic internalization policies; these policies increase private costs of production and this erodes market share and export revenue. Since, presumably, the country is unwilling to accept this loss, it is reluctant to implement internalization policies. Even if it uses these policies, the main effect may be to shift pollution abroad, along with market share: pollution "migrates". Section 2.2 considers this argument in greater detail, and illustrates with a simple model the likely order of magnitude of the effects of internalization policies.

In developed countries, the internalization of environmental externalities is in large part a matter of "getting the prices right", i.e. of insuring that private and social relative prices are roughly equal. This is also important in developing countries, but there the income effect of policies may be as significant as the relative price effects. If producers react primarily to income constraints, e.g., the threat of starvation or bankruptcy, then requiring that they internalize social costs may exacerbate environmental problems. For example, increasing the cost of fertilizer may lead to the abandonment of farms, deterioration of land, and greater overcrowding of cities. Here, income policies need to be associated with price policies. Section 2.3 considers this general issue and illustrates it with the case of sub-Saharan agriculture. We also discuss how some conclusions about international response to domestic internalization policies change when producers' decisions are determined primarily by income constraints rather than profit maximization.

Economists are broadly united in opposing the use of trade policy to achieve environmental goals. Many environmentalists support such measures. In Section 2.4 we attempt to provide a balanced discussion of this debate. Economic theory provides support for both positions. An important aspect of the disagreement can be viewed as the conflict between two mainstream economic ideas: "The Principal of Targeting" *v.* "The Theory of the Second Best". One's opinion on the relative merits the two positions depends in large part on one's view of the political process that determines policy. The judgement cannot be made on the grounds of narrow technical considerations, and still less, on the basis of a whether one believes that economic wealth is somehow more or less important than environmental protection.

2.2 Internalization, Loss of Market Share, and Pollution Migration

An important obstacle to the enactment of policies designed to internalize environmental externalities is the fear that these will lead to a loss in market share for domestic producers, and a decline in export revenue. For example, production of a crop that uses pesticides may lead to environmental degradation. A fertilizer tax causes these costs to be internalized, and raises producer costs. Unilateral internalization thus threatens market share and export revenue. By causing production to shift, the internalization policy may shift environmental damage to other countries. The benefit of environmental improvement in the country imposing the policy has to be weighed against these disadvantages in order to determine the optimal tax.

In order to make this comparison we would need to know society's willingness to exchange environmental quality for economic wealth. This type of issue is an active field of research. The methods are controversial, and because of practical limitations, we doubt if they will be useful in developing countries in the short run. Therefore, we take it as given that we do not know society's marginal willingness to exchange economic wealth and environmental quality. It is sensible to adopt the more modest goal of estimating (i) the environmental effects of not internalizing externalities, and (ii) the economic consequences of environmental policies.

Chapter 3 surveys information on the relation between the environment and some types of agricultural activity. Our knowledge is still rudimentary, but this is the sort of issue that can be illuminated by further research. The fact that this research can take the form of controlled experiments means that in principle we can determine whether production of a particular crop, or production by a particular method, is an important or a trivial source of environmental damage.

Understanding the relation between economic activity and environmental policies, such as pesticide taxes, presents a different kind of problem. We cannot use controlled experiments, but must rely on statistical estimates or informed guesses. Chapter 4, which surveys international trade models for several commodities, shows the extent of our uncertainty about key parameters. We do not know what estimates of supply and demand elasticities to use. Proponents of internalization have to concede that unilateral adoption of such policies is likely to erode competitiveness. The real issue, however, is whether this effect will be large or small, and what will be the effect on producer revenue. The recognition that there will be some loss in competitiveness, coupled with the inability to quantify this loss, is an obstacle to the adoption of internalization policies. A simple model provides rough estimates of the effects of internalization, on market share and export earnings. These estimates can be used to assess the argument against internalizing environmental costs because of a possible loss of competitiveness.

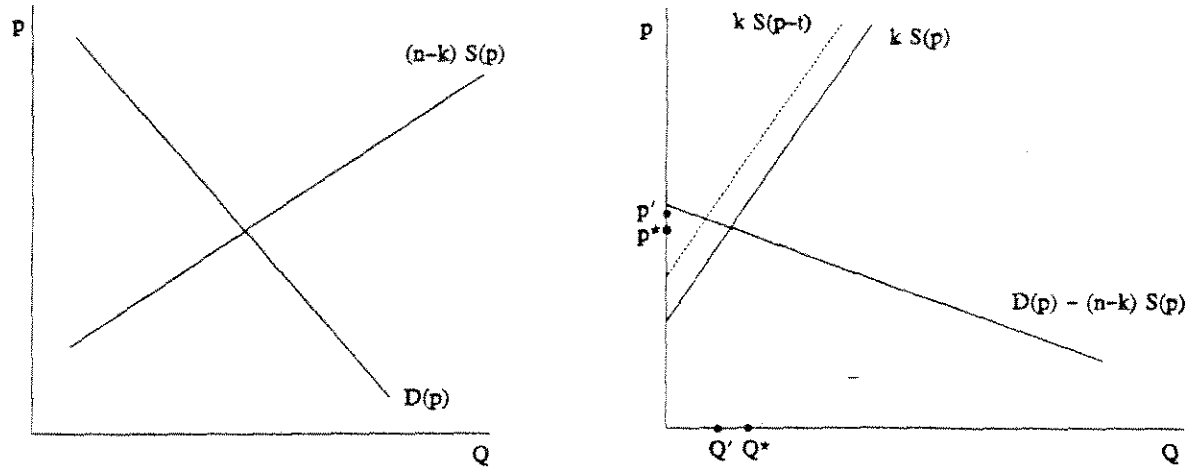

Figure 2.1a-b Equilibrium Effects of a Tax

Figure 2.1 illustrates this model. World demand is given by D(p), where p is world price. There are n producers (exporting countries), each with identical technology; k of these producers internalize environmental externalities, which results in an increase of t in their marginal costs. If the commodity output is directly taxed, t is an explicit tax; if inputs are taxed, resulting in higher costs, t is an implicit tax on output. The aggregate supply of the n-k producers who do not internalize the externality is (n-k)S(p) (Figure 2.1a), and the supply of the remaining k producers who do internalize is kS(p-t) (figure 2.1b). The tax of t raises the world equilibrium price from p* to p' and lowers exports of the k producers from Q* to Q'. The equilibrium condition for a competitive market, as a function of k and t, is
With S(p-t) as the equilibrium supply of one of the k producers, we can write R = pS(p-t) as

$$D(p) = (n-k)\,S(p) + kS(p-t) \quad . \tag{1}$$

export revenue, and M = S(p-t)/D(p) as their market share. We denote the supply and (absolute value of) demand elasticity at the pre-tax equilibrium as η^s and η^d. Suppose that the initial implicit tax is t = 0 (no internalization), and internalization involves a tax of dt > 0. The quantity dt/p gives the tax as a fraction of the initial price. With the assumption of competitive behavior, we can interpret this as the ratio of the tax and private marginal costs. This tax leads to an approximate proportional change in the equilibrium price (dp/p), in revenue of a producer who internalizes costs (dR/R), and in this producer's market share (dM/M), given by

$$\frac{dp}{p} = \frac{k\eta^2}{n(\eta^2 + \eta^d)} \quad \frac{dt}{p}$$

$$\frac{dM}{M} = \frac{-(n-k)\eta^2}{n} \quad \frac{dt}{dp} \tag{2}$$

$$\frac{dR}{R} = \frac{\eta^2\left[k - \eta^2(n-k) - \eta^d\right]}{n(\eta^2 + \eta^d)} \quad \frac{dt}{p}$$

The magnitude of dt/p depends on the application, but in most cases we expect it to be a small number, e.g., less than .1 (a 10% tax - see below). The effect of the tax on world price depends on the ratio of supply and demand elasticities, the number of producers who adopt the tax, and on dt/p. The magnitude of the market share effect depends only on the supply elasticity, the fraction of producers that internalize, and dt/p. The revenue effect also depends on the demand elasticity. If, for example, demand is very inelastic relative to supply, and k is close to n, internalization increases revenue of one of the k firms. This is because the fall in supply resulting from internalization leads to a more than proportional increase in price. It is as if the k producers exerted monopoly power.

Table 2.1 gives the percentage changes in market share, revenue and price when n = 10, $\eta_d = 0.5$, and a 10% tax is imposed in k countries. The column and row headings indicate the assumed value of η^s and k. The supply and demand elasticities are consistent with the estimates reviewed in Chapter 4. The elasticity of excess demand for one of n producers is $n\eta_d + (n-1)\eta_s$. This ranges from approximately 7 to 12 for the values used in Table 2.1. Thus, these values imply that a single producer faces very elastic export demand. The entries in Table 2.1 use the formulae in equation (2), multiplied by 100 to convert to percentages.

This exercise illustrates how to obtain a range of estimates of the effects of internalization. The model is transparent and requires only back-of-the-envelope calculations. The data requirements are minimal. We can easily understand how the results depend on elasticities, the size of the tax, and the fraction of producers who internalize the environmental costs. The results suggest plausible orders of magnitude for changes in market share, revenue, and world price resulting from moderate taxes. Even under fairly pessimistic circumstances, where only one country imposes the tax, and supply is quite elastic ($\eta_s = 0.8$), the loss in market share is only about 7%, and the loss in revenue 4%. If half of producers impose the tax, each of these still looses market share, but their revenues increase because of the price increase.

	$\hat{M}$	$\hat{R}$	$\hat{P}$	$\hat{M}$	$\hat{R}$	$\hat{P}$	$\hat{M}$	$\hat{R}$	$\hat{P}$
$\eta_s \setminus K$	1			5			8		
0.2	-1.8	-0.37	0.286	-1	1	1.429	-0.4	2.029	2.286
0.5	-4.5	-2	0.5	-2.5	1	2.5	-1	3.25	4
0.8	-7.2	-4.12	0.615	-4	0.308	3.077	-1.6	3.631	4.923

Table 2.1. Percent Change in Market share, Revenue, and Price
$n = 10$, $\eta_d = 0.5$, $dt/p = 0.1$

Despite its limitations, this illustration should at least make us skeptical about the claim that international trade is an impediment to domestic internalization policies. That claim may be true in situations where: the internalization policy requires a very large implicit tax; world demand and other producers' supply are quite elastic; and the reforming country constitutes a very small part of the market. Even in those cases, it is necessary to consider the economic benefits of environmental protection. Chapter 4 conducts the same type of exercise using a multi-commodity model which includes inputs, more varied policy instruments, and international differences. These experiments cannot provide definitive answers, but they may be useful for policy discussions, because they suggest likely order of magnitudes for the effects of policy changes.

The fear that internalization policies will erode market share and revenue is politically a more compelling argument, but there is also the worry that these policies will merely shift pollution. To the extent that pollution is strongly correlated with aggregate production, the simple model above provides an estimate of the likely effect, using the relation $dQ/Q = -\eta^d dp/p$. Unless internalization in one country affects world price, it will have no effect on aggregate production (and thus, little or no effect on aggregate pollution). For the example in Table 2.1, the percentage decrease in aggregate production ranges from a small fraction to about 25% of the tax; aggregate production always decreases.

There are two reasons to be cautious about concluding from this example that the net effect on aggregate pollution is negative, when one country internalizes environmental costs. Both reasons have to do with asymmetries across countries. First, the conclusion assumes that the relation between output and environmental damage is very similar in all countries. Where production practices and/or natural conditions vary, this assumption may be unreasonable.

Second, an internalization policy in one country may be offset by endogenous policy changes elsewhere. Producer price stabilization measures are an important example of such a policy. To illustrate what might happen, suppose that Country A exports fertilizer, which is also used for domestic agriculture. Country A requires its farmers to pay a tax on fertilizer, to internalize environmental costs. This decreases domestic demand for fertilizer, which increases exports and tends to reduce world price. Suppose also that country B insulates its domestic fertilizer producers from output price changes. The policy change in country A and the resulting fall in the world price of fertilizer triggers country B's stabilization policy. This offsets the supply reduction that would have occurred in country B, making more fertilizer available there. The net effect may be to increase aggregate world consumption of fertilizer, and thus increase environmental damage.

An alternative approach of evaluating the argument that internalization merely shifts pollution, is to estimate directly whether environmental policies affect the pattern of international trade. Tobey (1993) reviews this literature; Lucas et al. (1992) estimate the extent to which pollution "migrates". Empirical models do not find strong support for the migration hypothesis. There are several reasons why internalization policies may actually lead to pollution migration, but empirical models fail to pick up the effect. The first is that the implicit taxes associated with the policies have been small in the past. Various estimates suggest that pollution control costs are in the neighborhood of 3% of total costs for most industries; i.e., the quantity dt/p used in the formulae in equation (2) equals approximately .03. Empirical models may be unable to isolate the effect of such a small policy change. However, more effective policies may involve much larger implicit taxes, and therefor lead to larger changes. Second, there are serious data problems, as Lucas et al. discuss. For example, because of lack of better information, they assume (as does our simple model above) that the pollution intensity of a particular industry is constant across countries. Measurement error can make the empirical model unreliable.

The third reason why empirical models may be misleading is that the relation between internalization policies and industrial migration is probably very complicated, making it impossible to disentangle the effect of the pollution policy from other changes. The lumpy investment models studied by Dixit in a series of recent papers (e.g Dixit 1989) provide a plausible description of how decisions are made. Relocating a factory to another country is not a marginal choice. A firm relocates only if it can recoup the fixed costs of the move. For example, suppose that a firm decides to move only if the differential in labor costs exceeds a certain threshold. A change in pollution control costs alters that threshold. In the medium or long run, an increase in pollution control costs in one country may lead to a substantial migration of industry, although no such increase is apparent in the short run.

There is another aspect to the lumpy investment framework. If adjustment costs are continuous, then the amount of "stickiness" and the cost are of the same order of magnitude. However, when adjustment is lumpy, so that costs are discontinuous (or more generally, nonconvex), the amount of "stickiness" is of a higher order of magnitude than the adjustment costs. This means that in the short run at least, there would be relatively little adjustment, even though adjustment costs are moderate or small. Thus, it is plausible that the lack of empirical evidence for industrial migration following policy changes, is an accurate reflection of the short run, but not of the medium and long run. Simulation models incorporating lumpy investment would be useful to assess the likely magnitude of pollution migration. It would be interesting to compare the implications of such models, with those of the simple static model presented above.

2.3 The Income Effects of Internalization Policies

Above we assumed that the environmental damage in a region is strongly positively related to the level of production of a commodity. This means that if one country (or group of countries) internalizes the costs of environmental damage, the country's output of the commodity decreases (because domestic costs increase), as does the environmental damage there; output and environmental damage increase in countries that do not internalize costs. Thus, it appears that requiring producers to pay the full costs of their activities: (i) is an effective way of reducing domestic pollution, (ii) but the policy may do little to reduce global pollution, and it may carry a high economic cost as market share is lost.

These conclusions are based on a particular model (such as the one sketched in Figure 2.1) of how producers react to price signals. Although a number of different assumptions can support that model, the basic idea is that producers choose inputs to maximize profits in the current period. The environment is one of several inputs, and the market failure is that producers pay too little (or nothing at all) for it, and therefor use too much of it. Internalization policies increase the price producers pay, and thus protect the environment. However, this view of producers' behavior ignores the effects of income constraints on production. Inclusion of these effects may reverse the two conclusions in the paragraph above. Specifically, causing producers to internalize environmental costs may exacerbate environmental damage; also, internalization of costs in one region may lead to a decrease in environmental damage elsewhere, through induced policy change. We begin with an explanation of why domestic internalization policies may not lead to local environmental improvements, and then discuss an empirical example. We then consider the international effects of such policies when income or revenue constraints are important.

Some of the worst environmental problems are associated with poverty. Having to satisfy basic needs in the current period makes producers unable to look after the environment. What appears to be short-sighted behavior may simply be the effect of a binding constraint on current consumption. In this case, charging producers a higher price for an environmental input may exacerbate rather than correct the externality. This can be explained using the familiar concepts of income and substitution effects. A tax on the environmental input causes producers to use less of it; this is the substitution effect. However, the tax also decreases producers' real income. If the environment is a normal good (positive income elasticity), the loss in real income leads to less environmental preservation.

The income and substitution effects work in the opposite direction, so the net effect of internalization policies are ambiguous. In this setting we can think of the environment as a consumption good, and thus an argument of producers' utility function. Alternatively, we can think of the environment as simply an input into production, and view producers as solving a dynamic optimization problem. Smaller real income in the current period (due to the internalization policy) increases the value of a marginal unit of today's consumption relative to future consumption. This may decrease the shadow value of the environment; the shadow value incorporates the contribution of the resource to future production (and thus, to future income). The current environmental cost faced by producers is the sum of the explicit cost of using the environment and the shadow value. The internalization policy increases the former, but it may decrease the latter. Again, the net effect of the policy is ambiguous.

This point can be made very simply using Figure 2.2. The solid concave curve in the figure is a constraint representing the tradeoff between current income, Y, and the stock of the environment remaining for the next period, E. Utility, U(Y, E), is a function of these two variables. (We can think of U as the present value of current and future consumption; E determines possible levels of future income.) The initial equilibrium is at point A, where the indifference curve and the constraint are tangent. A tax increases producers' costs, so producers receive a lower level of income for each level of environmental stock remaining. This is indicated in the figure by the dotted concave curve. We have shown the tax-inclusive equilibrium as lying at point C. Here the income effect dominates the substitution effect, so the internalization policies lead to a deterioration in the environment. The figure also shows the effect, in the absence of a tax, of a current transfer of T to producers, increasing their current income to Y+T. In this case, the constraint relating Y and E is unchanged, but the marginal value, at point A, of an additional unit of Y is decreased. Only the income effect is operative, leading to an equilibrium at B, which has a higher level of environmental protection.

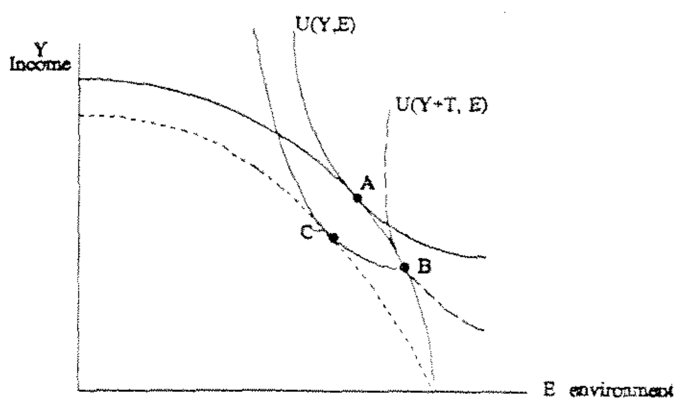

Figure 2.2

The message of this figure is simple but important: because of income effects, standard internalization policies may backfire. Much of the literature prescribing internalization policies for developed, richer nations, focuses on optimal policy design under imperfect information or strategic behavior. These, and similar considerations, may be less important in developing countries, relative to problems associated with poverty. In principle, it is straightforward to design revenue-neutral internalization policies. Such a policy eliminates the income effect, allowing the substitution effect to redress the environmental externality. In practice, revenue-neutral policies may be difficult to design, and harder to implement.

In proposing internalization policies it is important to take seriously the income effects. The simple supply and demand model discussed in the previous subsection, and the more sophisticated version studied in the Chapter 4, ignore these effects. Income effects are particularly relevant in very poor countries, but they are also important in lower-middle income countries, such as some of the formerly centrally planned economies of Eastern Europe and Asia. Although the absolute level of poverty there is not comparable to that of the poorest nations, the impatience for the fruits of reform makes it difficult to take the long view in protecting the environment.

The relation between poverty and the difficulty of using standard policies (such as producer taxes) to internalize environmental externalities is illustrated by the case of peanut and millet producers in the Sahel. Millet is a subsistence crop, for which there is very little trade. Peanuts, the cash crop, intensifies desertification. Golan (1992) estimates the likely income effects of two policies designed to internalize the environmental damage associated with peanut production. The first policy is a 20% tax on peanut production, and the second is a reduction in the government subsidy for peanut seed. The tax leads to a loss in income between 8 and 24%; the loss is largest for smaller producers. A reduction in the seed supply program, which is sufficient to reduce substantially peanut production, leads to a loss in income between 22 and 48% (Golan, Table 6).

However, the decrease in peanut production does not lead to adoption of environmentally safe production practices. There are few alternative production methods for the region, and virtually no market for the alternative crop, millet. Producers' efforts to protect their tenure rights, when peanut production decreases, may lead to extensive cultivation of millet which would also harm the environment. The likely effect of the income loss is to change tenure patterns and encourage migration from farming. Environmentally beneficial services, such as weeding and manuring, unlike peanut production, are relatively labor intensive. Therefore, the decrease in labor supply may lead to a direct worsening of the environment.

The main point of this example is that although environmental damage is closely associated with production of a particular crop, making that activity less attractive by imposing taxes or cutting subsidies may simply make matters worse. In order to improve the environment, reduction of production has to be accompanied by an increase in conservation; the latter does not automatically follow the former. This observation is widely applicable. May (1993) makes a similar point in discussing coffee cultivation in Brazil. Coffee production is associated with environmental damage, but the abandonment of coffee plantations following financial losses may result in still greater environmental degradation.

Golan's description of peanut and millet production in the Sahel not only illustrates the pitfalls of the obvious policy options, but it also shows why it is difficult to design better policies. An alternative to taxing a damaging activity is to subsidize a beneficial one. In this case, tree planting is a good candidate. However, encouraging tree planting may require large subsidies because of the nature of property rights. This rights are dispersed over members of a compound instead being vested in a single individual. Replacement of traditional property rights with the Western system might make it easier to encourage tree planting; in addition, tree planting could be made a condition for obtaining sole property rights. However, this institutional change dispossess other individuals currently enjoying property rights. These people are responsible for some cultivation, and their loss of property rights makes internalization even more difficult. Reallocation of rights would be politically and administratively challenging, and could also encourage fragmentation of fields.

Once the complexities of a specific situation are taken into account, the design of internalization policies ceases to be straightforward. Standard trade models based on supply and demand relations ignore income effects, and may lead the analyst to recommend policies which would exacerbate rather than alleviate environmental externalities. It is important to understand the "wealth and income effects", as well as the "substitution effects" of internalization policies. The design of income-neutral policies requires knowledge of institutional detail, such as the structure of property rights

These remarks may appear discouraging, since they suggest that many of the lessons learned from the study of internalization policies in developed countries need to be modified before they are applied to developing countries. However, there is an encouraging aspect. We saw in the previous section that the standard model of producer behavior implies that international trade tends to undercut unilateral internalization policies, both by re-allocating environmental damage along with production, and by making the policy expensive due to loss in market share.[1] These conclusions may be reversed in situations where individual producers are constrained by income, or producing nations are constrained by foreign exchange requirements.

For example, suppose that a nation relies on exports of a particular crop, or sector, to generate a required amount of foreign exchange, $\bar{R}$. When the world price is P, it must export E to satisfy $P \cdot E = \bar{R}$. A reduction in world price requires an increase in exports to satisfy this constraint. This model is too simple because $\bar{R}$ is not exogenous. However, a common hypothesis is that for some developing countries, a deterioration in the terms of trade has led to increased exports, in an effort to maintain imports. One implication of this hypothesis is that internalization efforts in one country can, by increasing world price, relax the foreign exchange constraint faced by competing exporters, and thereby increase the feasibility of internalization policies in those countries. Here we see that international trade promotes, rather than retards, the spread of effective internalization policies. The opposite conclusion is implied by the standard supply and demand model (described in Chapter 2.2) which concludes that international trade tends to be an (albeit small) obstacle to internalization policies.

Recent concepts borrowed from the field of industrial organization can be useful in explaining the different conclusions. A well-studied model in that field describes the interaction of a group of oligopolistic firms, each of whom tries to maximize its own profits, taking as given the behavior of its rivals. Depending on the specifics of the game, firms' policies may be "strategic substitutes" or "strategic complements". Policies are strategic substitutes if, when one firm changes its decision in way that benefits its rivals (e.g., by decreasing its sales), the rivals respond in a way that hurts the first firm (e.g., by increasing their own sales). Policies are strategic complements if, when a firm changes its policy in a way that benefits its rivals (e.g. by increasing its price) the rivals respond in a way that benefits the first firm (e.g. by increasing their own prices). There is a close analogy between the problem faced by oligopolistic firms and the problem of international environmental policy. We have described situations where internalization policy in one country may exacerbate environmental problems elsewhere (it is a strategic substitute), or may facilitate those policies (it is a strategic complement).

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[1] This is the qualitative prediction of the simple model. However, as our numerical example showed, the loss in market share and the redistribution of pollution may be very small, and the revenue effect could be positive or negative.

The trade model described in Section 2.2 is consistent with internalization policies being strategic substitutes. If one country internalizes environmental costs, this increases the market available for rival exporters, which tends to make internalization policies less attractive there. The discussion of income constraints in this section suggests a situation where internalization policies may be strategic complements. If one country internalizes costs, this tends to relax rivals' trade balance constraint (by increasing export prices), making it more attractive for them to internalize costs. There are probably many circumstances in which internalization policies are strategic complements. We have discussed perhaps the most obvious one in this section. Chapter 5.3 provides another example.

With the analogy taken from oligopoly theory in mind, we can draw on a further insight from that literature: If firms' policies are strategic substitutes, it may be disadvantageous for a group of firms to attempt to cooperate by forming a cartel, when the cartel does not comprise all firms in the industry. This "disadvantageous cartel" result occurs if the more cooperative behavior which is encouraged by this (partial) cartel, is more than offset by the increase in the aggression of the firms outside the cartel. Thus, with strategic substitutes, it is difficult for effective cartels to form, because they must be fairly large in order to result in higher welfare. The opposite is true when policies are strategic complements. There, a partial cartel cannot possibly make its members worse off, because their more cooperative behavior is rewarded by their rivals outside the cartel.

The same kind of result holds if we think of nations engaged in a game which determines environmental policy, in the presence of international trade. International trade may make international cooperation more or less likely, depending on whether environmental policies are strategic substitutes or complements. This interpretation of international policy does not provide a basis for recommendations: it does not help us in choosing one type of policy over another. However, the interpretation does help in explaining why certain commonly accepted ideas, regarding the relation between international trade on environmental policy, may be incorrect.

2.4 Trade Policy as a Means of Internalization

The fact that international trade and environmental change are related, does not imply that trade is inimical to the environment. Bhagwati (1993) provides a concise review of the relation between trade liberalization and environmental policy. Anderson (1992) explains why liberalizing trade in agricultural goods and coal is likely to benefit rather than harm the environment. There are, of course, dissenting views, such as those expressed by Daly (1993) and Lang and Hines (1993). In this section we discuss the use of trade policy as a means of protecting the environment. We consider the issue at a general level, and also as it relates to a specific proposal to resurrect International Commodity Agreements.

It is widely accepted that production and consumption rather than trade *per se* are the primary causes of environmental damage. However, since trade alters the patterns of production and consumption, it is at least worth considering the possibility that it is systematically related to environmental damage. It is possible to cite cases where reduction of trade barriers has been associated with environmental degradation; the maquiladoras along the U.S. - Mexican border are a common example. However, there are also counter-examples, such as those described by Anderson. Critics of liberal trade, such as Daly and Lang and Hines, do not assemble persuasive evidence that on balance trade is likely to worsen the environment. In a recent paper, Perroni and Wigle (1994) report the results of a world computable general equilibrium (CGE) model which includes environmental damage. As is the case for most CGE models, there are no empirical estimates for some key parameters, so the model is used primarily to illustrate "plausible" outcomes. The model suggests that the relation between increased trade and environmental change, although negative, is almost negligible. Also, environmental policies have little impact on the welfare effects of trade liberalization, just as trade policies have little impact on the welfare effects of environmental policies.

The most compelling argument against the use of trade policies to achieve environmental goals is based on the "principal of targeting"[2], which says that distortions should be targeted as directly as possible. For example, if the use of fertilizer results in an externality, fertilizer should be taxed, rather than taxing trade in a commodity which uses fertilizer. The basis for this principal is that indirect taxes introduce unnecessary distortions.

Critics of liberal trade have a ready responses to this application of the principal of targeting, viz, the "theory of the second best". These critics argue that although using a (suboptimal) trade policy to remedy an environmental problem does indeed introduce a distortion, the costs of that are likely to be small, while the benefits are likely to be large. The basis for this belief is that the world economy is "closer to free trade" than it is to "full internalization of environmental externalities". Although it is not possible to verify (or falsify) such a statement, it has a ring of plausibility: international attention has been focused

[2] We discuss this principal again in Chapters 3 and 5.

on trade liberalization for decades, whereas environmental concerns are relatively recent. If it is true that existing trade distortions are small in relation to existing environmental distortions, then the theory of the second best can be used to support the use of trade policy in the aid of environmental goals.

For example, consider the case of a small country that uses an ad valorem tariff τ, has an elasticity of import demand of η, and whose share of imports as a fraction of GNP, is α. Then the deadweight loss (DWL)[3], as a fraction of GNP, is DWL/GNP = $\tau^2\eta\alpha/2$. This welfare cost is proportional to the square of τ, so for small values of τ it is negligible. Even for a fairly large tariff, e.g. $\tau = .3$ (a 30% ad valorem tariff), and moderate elasticity and import share, $\eta = .25$, $\alpha = .2$, DWL/GNP is less than one half of 1%. Some estimates of environmental costs, reported in Chapter 3, are of similar or larger orders of magnitude. On the basis of these sorts of calculations, we cannot dismiss the possibility that trade restrictions might lead not only to environmental improvements, but also to increases in (standard measures of) economic welfare.

Even if one accepts that the welfare costs of environmental distortions are of a similar or larger order of magnitude than the welfare costs of trade distortions, it does not follow that protectionism *in general* would promote environmental interests. This is because trade *in general* is not associated with environmental damages. The theory of the second best can only be used to argue that specific trade policies might benefit the environment. The problem then is to identify those policies.

Critics of free trade sometimes also argue for the use of trade policies on pragmatic grounds. They point out that tariffs are administratively simple and generate revenue. Direct input taxes are more expensive to administer, and other environmental policies such as subsidies, burden public finances.

These arguments for the use of trade policy as an environmental remedy are unconvincing chiefly because of political-economy considerations. Although in principle it is possible to use trade restrictions to promote environmental objectives, we doubt that this would occur in practice. A host of special interests want trade protection, and environmentalists are just one of their number. As we emphasized above, in order for trade policy to benefit the environment, it would have to be finely tuned. There is no reason to believe that an increase in the general level of protection would benefit the environment.

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[3] This is a partial equilibrium measure; it is the familiar "welfare triangle". General equilibrium measures lead to welfare losses of similar orders of magnitude. It is difficult to construct a competitive general equilibrium model that shows large welfare losses from moderate trade restrictions.

A second reason to be skeptical of the use of trade policy involves the estimates of the welfare cost of such policies. We mentioned above that the approximation of the welfare measure is proportional to the square of the trade distortion (τ^2). Small tariffs lead to negligible welfare losses. This conclusion should be interpreted cautiously. It holds in a competitive environment without other distortions, and under fairly strong technical assumptions. Newbery (1990) describes a number of situations where imperfect competition, or missing markets, or externalities (such as learning by doing) dramatically change the conclusion that the welfare cost of small taxes is negligible. He calculates the welfare cost of taxes under several types of market imperfections, and shows that the true cost can be several times the loss as measured by our formula above.

In a similar vein, Romer (1994) explains why the welfare costs of moderate trade restrictions can be large if we relax the standard assumption that there are no fixed costs to introducing new products. (This is the technical assumption referred to above.) Under the assumption of no fixed costs, a small tariff has only a marginal effect on consumption or production; the tariff does not eliminate the surplus associated with "infra-marginal" units. If, however, trade protection reduces the set of available products or technologies, it eliminates the potential surplus associated with the infra-marginal units. This involves a large cost.

The claim that we might have under-estimated the welfare costs of trade distortions cuts both ways. That claim is really a criticism of the assumptions underlying our welfare measures. As such, it can be applied with equal or greater force to measures of the welfare costs of environmental distortions. Those costs may be much greater than estimates suggest. In view of this, it is difficult to establish whether, in general, welfare costs tend to be greater for trade or environmental distortions. Therefore we consider most persuasive the political-economic argument against using trade policy as an environmental tool.

The basis for that argument is a lack of confidence in the ability of the political process to distinguish spurious from legitimate claims for protection. If, however, restrictive trade policies are instituted under precise circumstances which are determined by international agreement, that objection is less compelling. We do not doubt the ability of domestic lobbyists to influence decisions of international policy, but when discussion occurs in an international forum it is harder to disguise protectionism as environmentalism. In the domestic arena, the interests of producers (who want protection) are usually more concentrated than those of consumers (who favor liberal trade), and the debate tends to be lopsided. The interests of opposing groups are more evenly matched in international negotiations, which also tend to be more technical and sophisticated. This does not suggest that international negotiations are more likely to arrive at an altruistic, or "correct" decision, or one free from political considerations[4] - merely that there is less danger of environmentalism being coopted into the service of protectionism under these agreements.

If this conjecture regarding the differences between domestic and international decision-making is accepted as a working hypothesis, then the theory of the second best might justify the use of internationally negotiated trade restrictions to promote environmental objectives. There have recently been proposals to create International Commodity-Related Environmental Agreements (ICREAs) (e.g., Kox 1991, 1994). Previous International Commodity Agreements (ICAs) were ostensibly designed to stabilize prices, although they have also been viewed as a means of making transfers from importers to exporters. The objectives of ICREAs would be to promote internalization policies, rather than stability. We consider the arguments for and against developing such an institution.

ICREAs have been proposed for commodities for which a large percentage of production is exported, such as coffee. If most of production is exported, a trade tax is a close approximation to a production tax. If, in addition, environmental damage depends on the level of production rather than the method of production, then taxing production is a good alternative to taxing the distortion directly. That is, if the following two assumptions hold, trade policy may be a relatively efficient means of achieving environmental goals: (i) a large proportion of production is traded, and (ii) there are no practical alternative methods of production that are less damaging to the environment.

It may be difficult for one, or even a group of exporters, to use an environmental-trade policy, for the reason discussed in Chapter 2.2.. Internalization of environmental damages by means of trade restrictions would be easier to sustain if importers are part of the agreement. If importers commit to buying only from producers who follow environmentally friendly practices, the temptation of exporters to "cheat", by taking advantage of their rivals' higher production costs, is much diminished.

Importing nations have been willing in the past to pay higher prices to support producer groups. In the case of the International Coffee Agreement, reviewed in Chapter 4, importers were apparently motivated at least in part by political considerations, such as the desire to retain strong ties with former colonies, or the desire to discourage revolutionary movements. Altruism is another possible motive for importer support. Other motives include

[4] It is not difficult to find international trade agreements whose wisdom is suspect (e.g., the Multi-Fibre Agreement, and various international sugar agreements.

enlightened or narrow self-interest. Enlightened self-interest includes the recognition that the environmental system is closed; even if pollution does not cross frontiers in an immediate and obvious manner, it does cross them in many subtle ways.

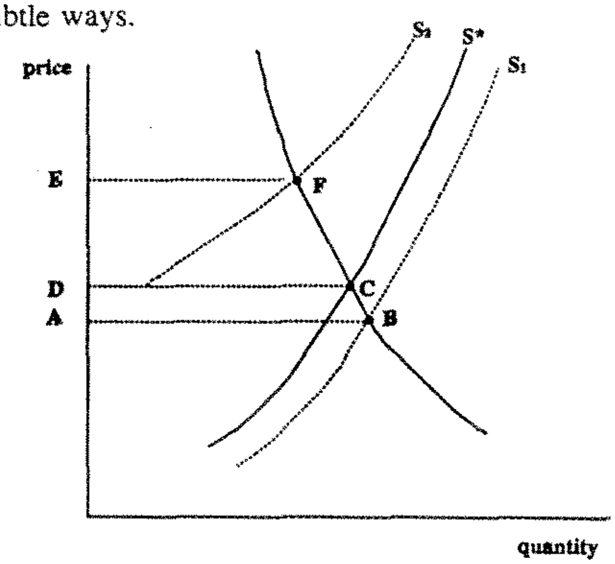

Figure 2.3

Narrow self-interest includes the recognition that importers as well as exporters benefit from trade. Environmental damage in producing regions decreases the surplus that importers receive, as Figure 2.3 illustrates. The current supply curve with environmentally unsustainable practices is S_1. Environmental damage causes the supply curve to shift, over time, to S_2. Sustainable environmental practices result in a supply curve of S^*, which lies between S_1 and S_2. The loss to consumers in the current period, if producers switch to sustainable methods, is the area ABCD. The eventual gain to consumers of the switch is the area CDEF. Depending on the relative magnitude of these areas, the period of time over which the change occurs, and consumers' discount rate, consumers may want to promote sustainable production for reasons having to do only with narrow self-interest. International trade is the mechanism by which economic surplus is distributed among producers and consumers in this case. It is therefore reasonable to at least consider the use of trade policies to ensure that potential surplus is not dissipated as a result of externalities. (Chapter 5 develops the model sketched in Figure 2.3.)

As we emphasized in Section 2.3, policies which change only relative prices may do little to decrease environmental damage, and may actually worsen it. Income transfers which make it possible for producers to take the longer view may be needed. One of the principal objectives of ICREAs is to finance these transfers. Kox (1994) describes an agreement which would tax trade and use the revenues to finance environmental improvements.

To summarize, the arguments in favor of ICREAs include: (1) They involve commodities for which the use of trade policies to meet environmental objectives is broadly consistent with the principal of targeting. (2) ICREAs are not likely to be co-opted by protectionists disguised as environmentalists. (3) They recognize the practical importance of cooperation by both importers and exporters. Importers have been willing to provide similar cooperation in the past. For reasons of either narrow or enlightened self-interest, importers are likely to benefit from cooperation in this case. (4) ICREAs provide financing for income transfers which are needed to promote improved environmental practices.

Despite these considerations, there appears to be no widespread enthusiasm for ICREAs. For example, UNCTAD (1994) and Beghin et al. (1994) dismiss them as serious contenders for policy. This rejection may be based in part on the associatioōn between ICREAs and ICAs, which are widely viewed as a failed policy experiment. Although the analogy between the two is important, it can be overstated. There were at least two reasons why ICAs failed. First, to the extent that their real *raison d'etre* coincided with the ostensible motive - to stabilize prices - the wrong instruments were chosen. Second, there was lack of clarity about the political reasons for the agreement, and the importance of income transfers in achieving the political goals. These mistakes need not be repeated.

However, there are valid objections to ICREAs. First, a rather narrow range of commodities satisfies the condition that a large percentage of production is exported (so that trade policies might be a good second-best policy option). For example, of the three commodities we study in Chapter 4 (coffee, cotton, and sugar), only coffee satisfies this criterion. Therefore, ICREAs offer a limited means of improving environmental problems. Second, by focusing on commodities that have a high ratio of trade to production, ICREAs inhibit North-South trade without affecting trade in many other commodities, the production of which is associated with equally severe environmental damage. It would be unfortunate to exclude from global efforts to liberalize trade, those countries which can most benefit from liberalization. Finally, political resources available to achieve international agreements are limited. There is the danger that negotiation of ICREAs would divert those resources from more promising alternatives.

A move toward internalization of environmental costs requires two things. The first is "getting the prices right", so that production and consumption decisions reflect social rather than private costs. The second is income transfers, so that policy changes are sustainable, and do not induce the sort of perverse responses described in Section 2.3. Trade restrictions in general do nothing to cause private and social relative prices to converge, and neither do they lead to income transfers. Specific trade policies, such as ICREAs, might improve price signals and they can facilitate income transfers. However, they have a limited range, and they impose restrictions on North-South trade, which is arguably the trade nexus which should be most encouraged.

In light of these considerations, it is worth reaffirming the general view amongst economists that trade policy should not be used to alter relative prices in an effort to achieve environmental objectives. At the same time, it is worth reaffirming the environmentalists' view that internalization policies in many cases require income transfers. Projects funded by transfers should be determined by multinational agencies, on the basis of environmental criteria. It is important to recognize environmental improvement as a distinct objective. In many, but not all cases, this objective will be closely correlated with the need for humanitarian and development aid.

This leaves the question of how the transfers should be funded. It seems self-evident that contributions to a global environmental fund should be correlated with national wealth. One possibility is to tie contributions to trade, i.e. to institute a non-discriminatory (across countries and goods) ad valorem tariff. If the tariff were collected directly by a multinational agency, the administrative costs would be prohibitive. If national contributions are determined on the basis of aggregate trade data, governments could have option of financing their contribution by means of the negotiated non-discriminatory tariff, or by general revenue. Even a very small tariff - small enough not to induce governments to want to decrease trade - would generate a great deal of revenue. This method of raising funds taxes open economies disproportionately, which benefits more closed, but richer economies such as the US. This would obviously be a source of friction, and might require ceilings on contributions, or other adjustments.

This proposal views trade as a source of revenue for environmental projects, rather than as a source of environmental damage. An important political advantage of the proposal is that it creates a coalition between environmentalists and free-traders. The latter recognize that a small *non-discriminatory* tariff introduces only a small distortion[5]. Whatever their deep misgivings about international trade, environmentalists would appreciate the fact that increased trade increases the pool of resources for environmental projects. The neoclassical objection to the proposal is that a better alternative would be to use "lump sum" transfers unrelated to trade flows. This is certainly true in principal, but we do not think that such transfers are likely to be forthcoming; in addition, they would do nothing to create an alliance between environmentalists and free-traders.

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[5] The tariff drives a wedge between the relative price of tradeables and non-tradeables, but not between the relative prices of tradeables.

2.5 Conclusion

This chapter has discussed several issues which are central to the relation between internalization policies and international trade. We began by reviewing the argument that foreign competition tends to undercut domestic internalization policies. This idea is easy to understand and is politically important. It has captured the popular imagination, and has led to increased concern about further trade liberalization. As a statement about the likely *direction* of the effect of trade on internalization policies, this belief is likely to be correct in many cases. However, the popular view probably overstates the *magnitude* of the relation. We provided examples which indicate that even fairly significant internalization policies lead to small losses in market share and ambiguous changes in export revenue. These examples are suggestive of the types of results that empirical models (of the sort described in Chapter 4) are likely to produce.

Environmentalists are probably wrong in supposing that liberal trade is a significant impediment to internalization policies. However, they are probably right in doubting that simply tampering with relative prices will be sufficient to lead to efficient use of the environment in many countries. Most of the theory of environmental regulation has been developed in the context of developed market economies where behavior is determined largely by price signals. In poorer countries, income constraints loom larger. In many of those cases, effective internalization policies will require substantial transfers. Price policies alone might simply contribute to the impoverishment of the world's most vulnerable, without correcting environmental degradation.

Although trade is not the cause of environmental problems, trade policy can be used to remedy them. However seductive, the temptation to do this should be resisted. General trade restrictions are as likely to harm the environment as benefit it. Trade restrictions which are narrowly targeted to environmental objectives can in principal improve both the environment and economic welfare. The history of trade policy makes us skeptical about the likelihood of this actually happening. We discourage the national use of trade policy to promote environmental objectives. International trade and environment agreements, such as ICREAs, are more likely to accomplish useful goals. However, there appears to be little enthusiasm for these, and in any case, they offer little scope for major improvements.

The important message for policy makers is that promotion of environmental goals requires both internalization policies *and* income transfers. Liberal trade policies are consistent with these goals. Trade policies should not be used to achieve internalization by altering relative prices; production and/or consumption taxes are less distortionary. However, the use of non-discriminatory, internationally negotiated tariffs as a means of funding income transfers, is worth considering as a policy option.

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3. Review of Damage Estimates and Internalization Measures

3.1 Introduction

An Overview of Environmental Damages Associated With Agricultural Activities

Externalities in agriculture cause inefficient use of valuable resources. A goal of economic policy is to allocate efficiently scarce resources. "Internalization mechanisms" are economic policies designed to correct the inefficiencies associated with externalities. The purpose of this chapter is: 1) to review studies attempting to quantify externalities associated with agricultural activities; 2) to review potential internalization mechanisms that might be used to correct these externalities; and 3) to summarize past, current, and proposed policies designed to address these problems. While examining agricultural externalities is our major focus, we will also review estimates of the private costs of inefficient agricultural production techniques to underscore the potential value of farmer education programs and international technology transfer efforts.

An overview of significant environmental damages associated with worldwide agricultural production and processing activities is presented in Table 3.1. These damages are difficult to quantify, especially at any level of aggregation, because agricultural activities have site-specific characteristics such as soil type and slope, rainfall, temperature, and wind velocity, that influence damage. Quantification is also hindered by the difficulty of observing and monitoring spatially diffuse agricultural processes. Analysis is complicated because the definitions of the various types of damages often overlap and depend upon one's perspective. Although the items in Table 3.1 are classified according to the damaging agent or the party damaged, an economist might classify them as extensive or intensive damages, a farmer as on-site or off-site damages, and an environmental regulator as point source or nonpoint source (NPS) damages. We discuss environmental damages from each of these perspectives in the course of our report. For the present, however, we examine the significance of, and the distinction between, point source and NPS damages.

Vigon (1985) defines NPS pollution by three characteristics: (1) it originates over large areas; (2) it is intermittent; and (3) it is not easily measured by structural techniques (pipes or weirs). Vigon writes: "Nonpoint source pollution remains as the primary reason for the designation of many of the nation's [U.S.] streams as 'water quality limited.' . . . even with the

Table 3.1. Environmental Damages Associated with Agricultural Activities

General Damage	Associated Problem
Soil erosion damages	Decreased soil productivity Increased soil salinity Increased stream salinity Decreased water holding capacity leading to increased flow irregularities (problem for agricultural and wildlife) Increased agrochemical runoff due to adherence to soil particles
Sediment damages	Accelerated reservoir siltation Blocked navigation channels and increased dredging costs Interference with water conveyance systems Increased costs of removal of sediment from roads and ditches Increased probability of floods Increased maintenance costs for roads, bridges Stream habitat degradation, harm aquatic plants and animals, genetic diversity losses Loss of mangrove forest wood stock, and associated fisheries habitat Degraded recreational resources
Over-irrigation damages	Accelerated depletion of groundwater stocks Increased land-subsidence associated with groundwater depletion Increased water-logging of soil Accelerated salinization of soil Increased salinization of groundwater Increased naturally occurring toxic leachates in agricultural drainage water Increased naturally occurring toxic leachates in groundwater
Agrochemical damages	Increased risks to agricultural worker health and safety Increased risks of contamination of groundwater Increased treatment costs for municipal intake water Increased treatment costs for industrial intake water Increased eutrophication of lakes, rivers and coastal areas, and increased costs of cleaning Increased weed choking in lakes associated with fertilizer runoff, and increased costs of cleaning Increased pest resistance Increased risks to wildlife, fish and plant health Costs of restocking lakes and rivers after fish kills Decreased recreational and commercial fish catches Genetic diversity losses
Soil compaction damages (from tractor use)	Decreased soil productivity
Deforestation damages	Increased soil erosion and sediment damages (see above lists) Increased crop damage from high winds Genetic diversity losses

General Damage	Associated Problem
Wetlands drainage damages	Biological productivity losses (decreased fisheries, waterfowl, or mangrove production) Decreased water purification services Genetic diversity losses
Air pollution damages	Dust from tractor use Odor from manure, decomposing crop wastes, etc. Smoke from diesel fuel from tractor use, crop dryers, coffee roasters, etc. Crop damage from air pollution, esp. ozone and sulfur oxides Increased risks to agricultural worker and health and safety
Costs of studies of these problems	

application of technology-based effluent limitations on point sources, ambient water quality standards will not be met." The nonpoint nature of most agricultural externalities limits the applicability of conventional policies used to combat point-source externalities. Dosi's (1992) study emphasizes the increasing importance of NPS issues in agricultural environmental policy. "Many contemporary problems . . . are caused by the combined activities of small polluters along with natural processes, intermittent and unpredictable events, and often involve pollutants with complex environmental outcomes." Dosi sites a number of examples, including acid rain from ammonia emissions due to animal manure spreading and groundwater contamination from nitrates and pesticides.

Griffin and Bromley (1982) note that the economic problem of agricultural NPS pollution can be separated into three distinct categories. First, the sediment, nutrients, and chemicals removed by runoff represent a loss of soil resources. These costs are borne privately by farmers. Provided he has adequate information regarding these costs and methods to prevent them, a reasonable farmer would undertake preventive or remedial actions to maximize the time-discounted profile. Second, if the discount rate of the individual farmer is greater than the social discount rate, or if the farmer has a planning horizon which is shorter than society's, the farmer will mine the soil resource more rapidly than is socially optimal. Third, physical resources lost by the individual farm must appear elsewhere in the environment. In sufficient quantities, these resources may become NPS pollutants, harming farm workers, nonfarm residents or their property, and aquatic or wildlife resources.

Data Sources

We have investigated two basic sources of data: Country or Case Studies and Macro-scale Aggregate Databases. Country or Case Studies are becoming available for an increasing number of countries, regions, and crops. These studies provide data for estimating changes in behavior due to internalization mechanisms. Examples include UNCTAD country studies and World Resources Institute case studies. We also want to have a measure of the aggregate impacts of changes in micro-behavior associated with internalization mechanisms to help determine the effects of internalization mechanisms on international commodity flows. For this purpose, it is not sufficient to gather information on "per unit" environmental damages (i.e., per bushel or per person). Because supply-response effects may by important, we also need aggregate information on, for example, the total number of hectares of crop X, or the total number of people affected by a given type of environmental damage. Macro-scale Aggregate Databases provide these data, which may be useful in translating changes in micro-level behavior into macro-level effects. Examples of Macro-scale Aggregate Databases include FAO Yearbooks, World Bank databases, and World Resources Institute databases.

Case studies can be used to derive estimates of environmental damages per unit of some relevant metric, such as crop area, crop production, head of livestock, input use, or agricultural population. We could then use these damage estimates to calibrate internalization mechanisms to promote efficient micro-level behavior. For example, one might set an internalizing tax rate on an agricultural input equal to the environmental damages per unit of its use. The aggregate implications of changes in micro-behavior could then be derived using data in the Macro-scale Aggregate Databases. For example, a 20% reduction per hectare in the use of a taxed environmental input might lead to a 5% reduction in crop yield per hectare. When multiplied by the total hectares of land planted to that crop, this might result in a significant change in world supply, affecting international trade in that crop and its substitutes and complements.

3.2 Environmental damage estimates from case studies

We review a selection of case studies of environmental damages associated with agricultural production and processing activities in developed, industrial countries, new market economies, and developing economies. We focus here on summarizing quantitative estimates of environmental damages. Additional descriptive information is in the Annotated Bibliography that accompanies this report. We discuss policies which attempt to address environmental damage problems in Section 3.4.

Few case studies give monetary estimates of environmental damages associated with agricultural activities in developing countries. However, it may be possible to derive estimates of such damages indirectly using existing information. For example, in many case studies data are presented in the form of "crop yield improvements possible with the implementation of conservation project X." The case study then presents the (generally positive) rate of return (ROR) or net present value (NPV) of the conservation project. In such cases, the increase in crop yield benefits, less the conservation project costs, is a measure of the environmental damages associated with the old, inefficient cropping practices.

The body of information collected on environmental damages associated with agricultural activities in the U.S. and the EEC is another source of information with the potential for extrapolation to developing countries. For example, symposium papers (Waddell, 1986) on the off-site costs of soil erosion in the U.S. provide dollar estimates. Although this work is for the U.S., the results may be useful for making order of magnitude cost comparisons across types of off-site damages in developing countries.

Our review of country studies provides an empirical database on environmental damages by type of environmental damage, geographic location, type of crop, type of farming method, date or season the damage occurred, and date the country study was done. The date is important when issues of research methodology arise or when factors taken by the study as exogenous change over time. We organize these data in Table 3.2, which shows country studies containing the following information: author, date of study, countries studied, crops considered, types of environmental damages identified, and policies discussed. This table can be scanned to locate environmental damage information for particular countries, crops, or types of environmental damages. We also present summaries of the quantitative environmental damage estimates found in the country studies, and organize this information by type of environmental damage. We begin with environmental damages due to the *extensification* of agriculture and proceed to damages associated with the *intensification* of agricultural activities.

Extensification Damages

Extensification damages are those associated with the expansion of agricultural land areas rather than with production methods on existing land. Extensification damages include deforestation, desertification, and wetlands destruction. We present only a brief summary of these damages.

Table 3.2. Damage Estimates

Author	Year	Crop	Country	Environmental Problems	Policy Dimensions
Abelson	1979	Sheep Cattle Crops	Australia	Soil erosion Dryland salting Siltation of road Irregularities of flows of river	"Soil Conservation Project"
Akande	1989	Cocoa	Nigeria	Excessive use of agrochemicals and pesticides	Green taxes
Anderson	1987	Firewood	Nigeria	Deforestation Desertification Soil erosion	"ARID ZONE Afforestation Program"
Bishop and Allen	1989	Groundnut Millet Sorghum	Mali	Soil erosion	
Bojo	1990		Lesotho	Soil erosion	"Farm Improvement and Soil Conservation Project"
Clarke et al.	1985		U.S.	Soil erosion Sedimentation Lost of recreational opportunities	
Cruz et al.	1988		Philippines	Soil erosion	
Duda	1985	agriculture	U.S.	Sediment in water Eutrophication	
Faeth	1993	agriculture	India Chile Philippines	Soil erosion	
Faeth et al.	1991	agriculture	U.S.	Soil erosion	Integrated Farm Management Program Pesticide record-keeping
Finney and Western	1986	forest agriculture	Philippines	Soil erosion Sedimentation of river	
Golitsyn	1992	agriculture Cattle	USSR	Soil erosion Arid pastures Water pollution	
Khalid and Braden	1993	Palm oil	Malaysia	High BOD	
Kim and Dixon	1986	agriculture	Korea	Soil erosion	

Author	Year	Crop	Country	Environmental Problems	Policy Dimensions
Mahar	1989	tree crops	Brazil	deforestation	Credit subsidy
May	1993	Coffee Cocoa	Brazil	Soil exhaustion Pesticide residues Air pollution	Emission charge Green Labeling New technology adoption Integrated pest management
Pagiola	1994	Maize Beans	Kenya	Soil erosion	Correct price distortion
Segura and Reynolds	1993	Coffee	El Salvador Costa Rica	Groundwater pollution Sedimentation Agro-chemical wastes	Emission Fees
Sfeir-Younis and Dragun	1993	agriculture	LDC	Soil erosion	
Solorzano et al.	1991	Corn Potato	Costa Rica	Soil erosion	
Southgate	1988	agriculture	LDC	Soil erosion	
Southgate and Macke	1989	agriculture	Ecuador	Soil erosion	
Southgate et al.	1984	agriculture	Dominican Republic	Sedimentation	
Witte et al.	1993	Rice	Thailand Philippines	Health problem Groundwater pollution Soil erosion	

Deforestation

Deforestation can damage biodiversity and eliminate supplies of non-timber forest products. In Brazil, for example, cocoa may be grown under the traditional "Cabruca" cropping system, which replaces the native forest understory with cocoa while retaining the native forest canopy. The alternative, a "clearcut" cropping system, replaces the native forest with a banana tree canopy and a cocoa and leguminous shade tree understory. Recent studies (May 1993) suggest that the Cabruca system is less detrimental to Brazil's threatened Atlantic Forest region than any other form of agriculture because it retains a range of threatened species. However, since the mid-1980's, market and environmental conditions have not favored cocoa farmers, and deforestation and illicit timber trade have become commonplace. Research has shown an inverse relationship between cocoa prices and forest area cleared for sale of timber. Such deforestation results in loss of wildlife and vegetation species diversity and productivity; unbalanced microclimatic conditions can cause uncontrolled fires, crop and livestock loss downstream, and shifts in the global carbon budget. Agropastoral expansion can cause ecosystem damage from pesticide residues, erosion, and sedimentation of watercourses.

Desertification

Overgrazing and poor implementation of grass cover restoration have resulted in increasing desertification in countries such as the former Soviet Union and India. Golitsyn (1992) reports that "In the Kalmykia and adjacent Dagestan republics the area of moving sands on pasture land has increased since 1954 from 15,000 ha to 1 Mha, and it is continuing to grow by 40-50,000 ha annually. Similar processes are observed in many places in Kazakhstan and the Middle Asian states. The Academies of Science of Turkmenistan and Uzbekistan have a wealth of experience in fighting desertification and transforming desert lands into productive pastures. The time needed for a return on the investment of making pastures in arid zones is four to five years. . ."

Khoshoo and Deekshatulu (1992) provide estimates of the land area subject to shifting cultivation in the North Eastern Region of India.

Wetlands Destruction

Wetlands drained for cultivation and pasture continue to compromise biodiversity worldwide. However, the useful role of wetlands is now being recognized, and in many regions they are now protected.

Intensification Damages

Damages associated with agricultural production and processing activities can be classified as either on- or off-site. On-site damages affect the agricultural production or processing activity causing the damage, while off-site damages affect other agricultural production or processing activities.

On-site Damages of Soil Erosion

Soil erosion reduces productivity in at least three ways: it reduces the soil's capacity to hold water; it restricts seedling emergence and root penetration; and it results in the loss of nitrogen, phosphorus, and potassium. Faeth (1991) studies two farming regions of the U.S.:

Nebraska and Pennsylvania. He estimates Net Farm Income (which includes government transfer but ignores environment) and Net Economic Value to Society (which includes environment but ignores government transfers) under a variety of government policy scenarios, including a 25% tax on farm chemical inputs. Faeth also outlines a method for calculating lost farm income due to the on-site damages of soil erosion. Dawkins et al. (1994) develop a full-cost, life-cycle case study of spring wheat production in the Northern Plains of the U.S. They estimate the cost associated with decreased soil productivity as $58.67 per bushel, and the private cost of production of spring wheat at $8.94 per bushel.

Conacher (1990) discusses the environmental damages associated with agricultural production in the Australian Wheat Belt. In 1983, the director of the Western Australian Department of Agriculture estimated that wind erosion was responsible for $38 million in production losses annually. Golitsyn (1992) estimates that, in the former Soviet Union, soil erosion reduces the value of production by 36 to 47%. Khoshoo and Deekshatulu (1992) edit a volume on land and soil problems in India which compares soil loss and yield across crop types and cropping methods; provides estimates of soil erosion by Land Resource Regions; and describes the distribution of salt-affected soils. It also compares mean soil loss to wind erosion under different cropping methods; presents gross estimates of erosion-susceptible land areas; and provides information by state on land areas degraded by ravine erosion.

Faber (1993) notes that in El Salvador, overexploitation in cotton production is causing extensive fertility loss, soil erosion, ravine and gully formation. More than 77% of the country suffers serious soil erosion. An estimated 16 to 20 tons per hectare of topsoil were being washed and blown from the cotton fields each year. Trees necessary to protect the fields from wind erosion are removed to facilitate cheaper forms of pesticide application by aircraft. Rather than practicing crop rotation, weeds and protective ground cover are also eliminated because they might host potential cotton pests. Solorzano et al. (1991) calculate the value of loss in soil productivity due to soil erosion in Costa Rica using a linear programming model. They provide estimates of depreciation due to soil erosion as a percentage of agricultural value added; 68% in 1987, 7% in 1988, and 5% in 1989. Pimentel (1993) discusses soil erosion in Argentina, where approximately 24% of agricultural land is affected. He reports the cost of replacing soil nutrients lost through erosion to be $5000 million per year.

May (1993) examines the soil erosion due to coffee and cocoa production and processing sectors in Brazil. He refers to a study by Bertoni, et al. in 1972 which compared perpendicular to contour planting systems on steep slopes. Soil losses were reduced from 4.4

to 3.1 t/ha, and rainfall runoff by 25%. Planting grass within coffee groves reduced soil losses to 0.2 t/ha, and rainfall runoff by 90%. Soil erosion control increases organic matter, which helps to control nematode problems.

Magrath and Arens (1989) discuss the on-site costs of soil erosion on Java. Productivity loss due to erosion has several effects on farming systems: profits can fall as the result of lower output; farmers can be influenced to make radical changes in the mix of crops and the level of input use; and, in extreme cases, erosion may lead to the complete withdrawal of land from cultivation. To calculate the impact of erosion-induced productivity loss on changes in net farm income, they assumed that as output falls farmers adjust variable inputs in proportion to yield declines with no change in fixed costs; they conclude that the annual capitalization cost of erosion is approximately 4% of the value of six major rainfed crops.

Costanza et al. (1990) analyze farming practices that increase sustainable production in the barley-cropping area of Jordan. They examine soil and moisture management alternatives, including conserving technologies for semi-arid conditions where wind and water erosion would otherwise make sustainable agriculture unlikely. Erosion is accelerated by extensive use of conventional tillage techniques. Preliminary results indicate that conserving and incorporating crop residues increase grain yield, conserve soil, and reduce feed supply available for livestock production.

Bishop and Allen (1989) study the on-site costs of soil erosion in Mali and estimate the annual net farm income lost due to continuous cultivation at $31 to $123 million. They report declining yields, ranging from 12 to 83%, for groundnut, millet, and sorghum under continuous cultivation from 1931-1955.

Pagiola (1994) discusses the returns to soil conservation policies in Kenya. For example, on a 15% slope with conventional tilling and a crop of maize and beans, soil erosion causes a 20% decline in productivity in 10 years and a 40% decline in 20 years. However, given the high cost of terracing and the low crop prices, an investment in soil conservation is not repaid until the 48th year.

Dazhong (1993) and McLaughlin (1993) review soil erosion in China's Gansu Province. On the Loess Plateau organic matter, nitrogen, and phosphorous are 10% or less of original levels. Soil erosion in the region is correlated with population growth and has reduced crop yields by 30 to 69%. McLaughlin provides figures on the increased productivity of areas where soil conservation programs are used.

Conacher (1990) surveys the environmental damages associated with agricultural production in the Australian Wheat Belt. For thousands of years salt has accumulated in both the groundwater and the deeply weathered soils of Western Australia. The transformation from natural vegetation to agriculture in this region has disturbed the soil layers and the hydrologic cycle so that salt moves toward the surface. In 1983, the director of the Western Australian Department of Agriculture estimated that salinization was responsible for $26 million of production losses annually. Soil acidity also appears to have increased, and the older agricultural areas are most affected.

Kim and Dixon (1986) used a cost-effectiveness analysis to examine two alternative methods of avoiding soil erosion and soil-nutrient losses in Korea. The prevailing method involves replacing soil and soil nutrients in the uplands and clearing silted paddies in the lowlands; the alternative method requires mulching the upland areas. The benefits associated with implementing either method were not estimated, but they were considered to exceed the costs.

Southgate et al. (1984) examine the problems associated with soil erosion in the Valdesia Watershed in the Dominican Republic. Soil erosion there results in private damages to farmers due to reduced soil productivity and social damages to the region due to accelerated loss of storage capacity in the Valdesia reservoir. The authors estimate both private and social net present values of proposed soil conservation policies. Although farmers on gentle slopes have large private incentives to implement the policy, farmers on steep slopes do not. Their analysis reveals that the region as a whole has a very large incentive to persuade farmers on steep slopes to implement the policy. The discrepancy between private and social implementation incentives on steeply-sloped land suggests a need to develop appropriate internalization mechanisms.

The Kim and Dixon (1986) and Southgate et al. (1984) studies provide good examples of the links between the on- and off-site costs of soil erosion. We now turn to a more thorough examination of off-site damages caused soil erosion.

Off-site Damages of Soil Erosion

Sedimentation Effects

Southgate (1988) reports that soil erosion and sedimentation can affect the frequency and severity of flooding. Runoff from non-eroded watersheds tends to be less variable because topsoil holds water better than other strata. The frequency with which water breaches stream banks is a positive function of the amount of eroded material accumulated in steambeds. In watersheds containing reservoirs, sedimentation causes loss of storage capacity, and eroded materials may pass into generators and irrigation systems, damaging machinery and clogging irrigation canals.

Clark (1986) presents estimates of the off-site costs of soil erosion for the U.S. He surveys recreation, water storage facilities, navigation, fisheries, property and preservation values, flood damage, and water conveyance facilities. In the same volume, Ribaudo (1986) divides the U.S. into regions, estimates total off-site soil erosion costs, and provides cost breakdowns for: recreation; water storage facilities; navigation; commercial freshwater and marine fisheries; flood damage; drainage and irrigation systems; municipal water treatment, municipal and industrial users, and steam electric power plants; and salinity. Faeth (1991) updates Ribaudo's figures. Using these data, Dawkins et al. (1994) estimate the environmental cost of water pollution to streams and rivers (excluding lakes and groundwater) from spring wheat production to be $3.61 per bushel. They estimate environmental damage to wetlands at $44.00 per bushel; this compares to $8.94 per bushel, the estimated private cost of spring wheat production.

Malik and Faeth (1993) analyze the costs associated with canal sedimentation from agricultural soil erosion in the Punjab region of India at about Rs 43 per ton of eroded soil. Segura and Reynolds (1993) note that coffee production in Costa Rica has resulted in the removal of shade trees, which has caused an increase in the sediment load of nearby rivers. Faber (1993) estimates that in El Salvador, 16 to 20 tons of topsoil per hectare are washed and blown from the cotton fields each year. Sedimentation from cotton fields also contributes to the destruction of El Salvador's marine habitats. In Argentina Buck (1993) found that, for each ton of cereal exported, an equivalent amount of silt must be dredged from the port of Buenos Aires. In 1983, $61,250,000 was spent to dredge silt from the port; this amounts to $1.50 for each ton of cereal exported. Dazhong (1993) reports that the Loess Plateau region in China's Gansu Province lost approximately 30% of reservoir storage capacity and 48% of irrigation capacity from 1949 to 1975 due to sedimentation from the Plateau.

Magrath and Arens (1989) discuss the costs associated with irrigation system siltation in Java. Silt causes higher operation and maintenance (O&M) expenditures and lowers operating efficiencies, decreasing returns to irrigation investments. They analyze the total operation and maintenance costs of Javanese irrigation systems to demonstrate the cost of siltation. World Bank engineers estimate that the portion of O&M expenditure due to silt removal is 15 to 20% of cost. Indonesian irrigation authorities calculate that silt removal costs are $0.67 per cubic meter. The authors report the level of dredging in the major harbors of Java from 1979 to 1986. Based on available data for nine major reservoirs on Java, the authors summarize capacity reduction due to sedimentation.

Southgate and Macke (1989) estimate the off-site benefits of soil conservation for a project to reduce erosion in a hydroelectric watershed in Ecuador. They calculate the benefits of maintaining the service level of a hydro project while conserving given levels of reservoir and generating capacities. They also consider the savings from reduced expenditures on remediation such as removing soil and rock from the dam. They estimate the cost of soil erosion on the sedimentation of the reservoir as well as on the lifetime of the hydro facility. The results of their model show the benefits of different watershed management techniques but do not estimate losses associated with no management.

Off-site Damages of Agricultural By-Products

Most coffee in Brazil is dry processed, resulting in the by-product of hulls and hull lining (May, 1993). Hull lining is often dumped directly into rivers. The wet process is more complex and requires more capital, energy, and worker training. It causes pulp disposal problems as well as water pollution. The biological oxygen demand (BOD) from sugars generated in wet processing one ton of raw coffee is equivalent to that generated by the domestic waste of 2,000 persons (Gathuo et al., 1991). The pulp residues from this process have a high moisture content, and their lechate can pollute neighboring streams. The secondary processing associated with the manufacture of soluble coffee produces both a residual liquor and a sediment by-product. Most liquor wastes are dumped directly into watercourses or sewage treatment plants. Sediment residues are compressed to reduce water content and then used as animal silage, fertilizer, fuel, or landfill.

Segura and Reynolds (1993) note that waterways in Costa Rica are polluted with water from coffee processing as well as sediments, agro-chemical wastes, municipal, and industrial wastes. Most surface water cannot be used for human consumption, irrigation, or even recreational activities. Wet processing coffee is a water-intensive procedure, requiring 3 to 4 cu.m. to process 240 kg. of coffee. In Costa Rica, this water is not treated before it is discharged to rivers. This organic discharge amounts to 275 tons/day, and is concentrated in the coffee-harvesting period of November through February. This period coincides with the dry season in Costa Rica, which exacerbates the problem because rivers are at low flows. Coffee processing contributes an estimated 66% of the total BOD in the country's rivers.

Khalid and Braden (1993) discuss water pollution associated with palm oil manufacturing in Malasia. Residue from the oil-processing process creates high BOD when dumped into waterways.

On-site Damages of Over-Irrigation

Mercer and Morgan (1991) review the externalities associated with over-irrigation in the San Joaquin Valley of California, including accelerated depletion of groundwater stocks, waterlogging of soil and land subsidence.

Conacher (1990) estimates that water erosion and waterlogging annually were responsible $19 million in production losses in the Australian wheat. Increased surface water repellence also contributes to accelerated soil erosion.

Malik and Faeth (1993) examine the environmental damages associated with several alternative crop production regimes in the Punjab region of India. This region produces rice in the wet season and wheat in the dry season. Groundwater is currently used at about 15% above recommended levels, and water tables are falling about 0.8 meters per year. "Under the rice-wheat rotation at 15% over-irrigation, a typical farm's operating costs would triple over 25 years owing largely to the need for progressively larger pumps."

Off-site Damages of Over-Irrigation

Johnson (1986) calculates the direct costs to agriculture and municipal agencies, and the indirect regional costs to the Colorado River Basin, associated with various levels of salinity in the Colorado River. He also estimates micro-level household costs associated with high salinity in the Colorado River.

Klasing (1991) discusses the potential effects of heavy metal and nitrate-contaminated agricultural drainage water on human health in California's Central Valley. Mercer and Morgan (1991) review the naturally-occurring toxic leachates in agricultural drainage water in the San Joaquin Valley of California.

Golitsyn (1992) notes that, in the former Soviet Union, because agriculture uses almost all the water from the AmuDarya and Syr-Darya rivers, the Aral Sea is catastrophically shrinking. This phenomenon has been labeled the Aral ecological crisis. "The fast decrease in the Aral sea level, about 1 m per year, denudes its bottom, and winds blow salt and dust to distances of more than 500 km away, which increases the salinization of the soil."

On-site Damages of Pesticide Use

One of the most emotional, and potentially one of the most costly, environmental damages associated with agricultural activities is the effect of pesticide use on human health. It is difficult to quantify the effects of pesticides on either farmworker or consumer health because there are several links in the chain of events from agricultural spraying to health damage. Although the U.S. EPA and the FAO have investigated the dosage-response link and set various dosage limits and health effects thresholds for many pesticides, estimating the number of persons exposed to pesticides and quantifying the link between exposure and dosage is difficult. The FAO (1993b) has recently developed methodology, based on global diets, to screen out some pesticides from a list of contenders that might cause health effects through food consumption.

Rola and Pingali (1993) investigate the effects of pesticides on the health of rice farmers in the Philippines. They list the hypothesized health effects caused by chronic exposure to pesticides and compare the prevalence of actual health effects in an exposed and control group of farmers. The authors also supply micro-level information from the town of Neuva Ecija, estimating mean health cost for the rice farmers there, detailing the percentage of farmers who use unsafe pesticide spraying practices, reenter fields too soon after spraying, and store and dispose of pesticides unsafely. A large number of pesticides which have been banned in other countries are still used in Thailand and the Philippines (Witte et al., 1993).

Faber (1993) reports that, in El Salvador and Guatemala, intensified use of phosphate-based pesticides is responsible for 400 worker deaths annually. Surveys conducted in 1988 and 1989 by the Nicaraguan Ministry of Health show that 12% of small farmers in the country's principal agricultural region reported being poisoned at work. A major cause of the long-term contamination of the land surface, water table, and food chain is the use of aircraft spraying, which produces smaller and more concentrated droplets. From 50 to 75% of these droplets never reach the crop, but drift up to five miles or more.

Several cotton pests in Central America developed resistance as insecticide use became widespread. By the mid-1960s this had led to even more extensive use of pesticides, a situation known as the "pesticide treadmill." Another effect of the pesticide treadmill was a new outbreak of malaria that affected millions of Central Americans. Malaria is transmitted by the bite of anopheline mosquitoes, which developed resistance to the standard chemicals used by cotton growers. Poor soil conservation practices, combined with heavy pesticide use, further destroyed the beneficial microorganisms, insects, and earthworms necessary for soil vitality. To combat the pesticide treadmill and the crisis of cotton agroexport, growers adopted a number of alternative strategies. Many diversified into other export crops (i.e., mechanized rice and sugar production); however, these products were sometimes contaminated by pesticide residuals from cotton production.

Weinberg (1991) describes environmental problems associated with the pesticide treadmill generated by cotton cultivation in Central America. The humidity and heat of the Pacific zone provide fertile breeding conditions for insects, and there is no winter frost to keep insects in check. By the 1970s Central America was the world's highest per capita user of pesticides; 75% of the pesticides it imported from the U.S. were either banned, restricted, or unregistered there. Nicaraguans and Guatemalans are estimated to have a higher concentration of DDT in body fat than any other population. During the 1960s and 1970s Honduras and Nicaragua were the world leaders in per capita illness and death from pesticide poisoning. Every year, more than 1,000 Guatemalans receive medical treatment for exposure to pesticides—many more may suffer without access to medical care.

Chemical pesticides are used widely in the coffee and cocoa production and processing sectors in Brazil (May, 1993). In the 1970s increased use of BHC and Lindanc, the recommended organochlorides, caused many pesticide intoxication problems. In the 1960s the government advised cocoa growers to eliminate some shade trees and apply fertilizers. Among other chemicals, the government subsidized use of Agent Orange. While pesticide misuse continues to be a serious problem in the cocoa zone of Bahia, overall use has decreased sharply since 1985. There has not been a correspondingly sharp fall in yields.

On-site Damages of Soil Compaction

In the northern plains of the U.S., Dawkins et al. (1994) report that the cost due to soil compaction in Spring wheat production is $.52 per bushel, or approximately 5% of the private cost of production. Golitsyn (1992) estimates similar crop losses in the former Soviet Union at 5 to 25%. Conacher (1990) estimates that deteriorating soil structure is responsible for $11 million in production losses annually in the Australian wheat belt.

Off-site Damages of Fertilizer Use

Lake Ladoga, the largest lake in Europe, is being polluted by 7 paper mills, a large aluminum plant, and intensive agriculture. This has endangered St. Petersburg's water supply (Golitsyn, 1992). Phosphorus has increased by 300% over the last 30 years, and nitrogen has increased by about 30%. Fertilizer run-off is a major problem. Khoshoo and Deekshatulu (1992) present similar data for India.

Nitrogenous fertilizer use was expanded in Costa Rica after 1975, following the increased density of coffee plants and the loss of leguminous shade trees. Fertilizer use is a primary cause of the increase in nitrate in the groundwater used for drinking in the Costa Rican Central Valley (Segura and Reynolds, 1993). Recent studies on groundwater contamination from fertilizer nitrates in the Virilla watershed found levels exceeding WHO recommended limits. Nitrates in drinking water have been linked to metahemoglobinaemia and gastric cancer. Fertilizer use is responsive to crop price; the fall in coffee prices since 1989 has resulted in decreased use of fertilizers.

Rice production in Thailand and the Philippines uses synthetic fertilizers (Witte et al., 1993). Because these inputs are not available to many farmers, there has been widespread underfertilization, i.e. "soil mining". Pingali et al. (1990) found a declining yield trend in both on-station and farmer-irrigated rice, which they attributed to environmental degradation. "Probably not more than 10 to 15 percent of soluble phosphorus added to the soil is absorbed by the crop due to fixation."

On-site Damages of Air-Polluting Activities

Brazil's dry-processed coffee production generates dust that contains allergenic compounds, chiefly chlorogenic acid (May, 1993). Various studies have found 4 to 92% of exposed workers develop asthma, rinitis. or dermatitis. Secondary coffee processing (roasting) produces a dense smoke containing a large quantity of fine particles. Roasting also produces organic gasses including alcohols, organic acids, and sulfur and nitrogen oxides.

Off-site Damages of Air-Polluting Activities

Waddell (1986) estimates the total cost of wind erosion damage to New Mexico's Major Land Resource Areas by examining costs to households, businesses, irrigation and conservancy districts, county road and state highway maintenance. Dawkins et al. (1994) estimate environmental damages from air pollution associated with the diesel fuel used for Spring wheat production in the northern plains of the U.S.to be $.001 per bushel. Rice paddies, especially those under irrigation, contribute an estimated 5 to 30% of atmospheric methane, which contributes to global warming (Witte et al., 1993).

3.3 Macro-scale aggregate databases

Aggregate data can provide an international perspective on the populations and land areas affected by the environmental problems described in the case studies. These data provide information on the potential magnitudes, likely geographic distribution, and relative importance of environmental problems. Often these environmental damage estimates are reported in detail (i.e., "dollars per irrigated acre" or "percent of coastal fish population affected"); these data may provide the links between the micro-level effects of internalization and the aggregate impacts of internalization on country-level production and trade flows. Some relevant data sources are listed below.

FAO. 1991. Fishery Statistics Yearbook.
FAO. 1992. Fertilizer Yearbook.
FAO. 1993a. Forest Products Yearbook.
FAO. 1993c. Production Yearbook.
OECD. 1991. Environmental Indicators - A Preliminary Set.
UNEP. 1993. United Nations Environment Programme Annual Report 1992.
World Resources Institute. 1994. World Resources 1994-95.
World Bank. 1993. Commodity Trade and Price Trends: 1989-1991.

3.4 A Review of incentive-based policy instruments

A recent report by the OECD (1993b) examines the potential role of economic instruments for environmental management in LDCs, where controversy continues over what kind of government intervention is necessary or justified. In DCs, governments historically regulated resource users and polluters through rigid "command and control" methods, setting limits on *levels* of resource exploitation or pollution generation. However, there are valid reasons why command and control regulations do not work in the majority of LDCs and why market based incentives have a better chance. For example, following the DC model, environmental regulations in LDCs stipulate terms of imprisonment and/or fines for noncompliance. However, many developing societies, most notably in Asia, are not given to litigation. Because courts are rarely used, regulations become "paper tigers". It is difficult for LDCs to monitor hundreds or thousands of scattered, small-scale operations which each generate little pollution but together account for the bulk of pollution emissions. There also is a mismatch between the high costs of regulation, monitoring, and enforcement, and the manpower and administrative constraints in LDCs. In addition, fines are too low to deter violations; since the probability of apprehension is very low, fines should be high enough to exceed the benefits from the violation. A final flaw of command and control regulations in LDCs is the rent-seeking behavior they elicit. Violators are willing to pay a fraction of the stipulated fine to the enforcement officials as a bribe. Increased fines or stricter enforcement predictably lead to more bribes rather than less environmental degradation.

An alternative is indirect regulation using economic incentives to "internalize" environmental externalities. Economic incentives have many advantages over regulations. First, they can achieve the desired effect at the least possible cost. Second, they are easier to enforce. Third, they present fewer opportunities for rent-seeking behavior; therefore, they are likely to be more effective and more equitable. Finally, unlike regulations, economic incentives generate revenues which may be used to finance the incentive program in the face of tight budgets and budgetary deficits.

The policy instrument or mix of instruments that should be chosen depends on the nature of the pollution problem. In the case of large numbers of small polluters, where monitoring imposes practical difficulties, a tax on polluting inputs may be a second-best policy. However, the efficiency of such a tax would depend on whether the quantity of input purchased is closely correlated with the volume of pollution emissions generated. More importantly, the effectiveness of this instrument depends on the elasticity of the input demand response to the higher input prices.

We review below the policy instruments that could be used to influence the economic incentives to engage in environmentally-damaging agricultural activities. Our discussion draws heavily on Dosi (1992). Depending on the specific legal environment, some of these policy instruments may be unavailable to administrators. Policymakers should investigate possible municipal, state, national, or international legal constraints on internalization mechanisms. If the administration of internalization programs is financed through income or commodity taxation, any deadweight losses associated with such taxation should also be considered in the development of incentive-based policies.

Remove Existing Market Distortions that Exacerbate Environmental Damage

Although agricultural activities can be expected to produce externalities even in a complete policy vacuum, many externalities are exacerbated by government programs which distort relative prices. For example, the U.S. price support programs were designed to maintain farm incomes but provide incentives for over-production and over-specialization in crops that require large levels of agrochemical inputs. Incentives for over-production lead to the expansion of environmentally-damaging agricultural activities at both the extensive margin (e.g., deforestation and filling wetlands) and intensive margin (e.g., overuse of agrochemicals and irrigation water). In the EEC, the Common Agricultural Policy creates similar distortions. In many LDCs agrochemical subsidies provide incentives for the overuse of environmentally-damaging chemicals at the expense of traditional manuring and crop rotation practices as well as modern conservation-oriented cultural methods.

From the previous review of case studies, it is clear that existing market distortions are responsible for a large proportion of the environmental damage caused by agricultural activities around the world. These distortions increase over-production, over-specialization, and over-intensification. Although removing market distortions would seem to be a technically straightforward way to reduce environmental damage, this is also one of the most difficult policies to implement from a political point of view. Interest groups can be expected to fight for the economic rents that accrue to them under existing policies.

Emissions Taxes or Marketable Emissions Permit Systems

Emissions taxes are direct taxes on the activity or substance that causes problems; e.g., taxes on eroded soil leaving farmland, on pesticides harming farmworkers, or on fertilizers polluting groundwater. If emissions taxes per-unit of externality-causing activity or substance are set at rates equal to the marginal per-unit level of damages caused by an externality, then profit-maximizing agents would reduce the externality-causing activity or substance emissions to socially efficient levels. In principle, emissions taxes are superior to taxes on outputs or inputs because emissions taxes do not cause additional distortions in output or input markets. In practice, however, emissions taxes are difficult to implement because the externality-causing activity or substance and the damages caused by the externality must be measured in order to calculate the appropriate tax rate. Such measurements are very difficult in the case of nonpoint source pollution emissions because sources are spatially diffuse, damages are often distant from sources, and are the result of emissions from several sources. An alternative approach is to use mathematical models to estimate emissions based on soil type and slope, input use, cultural practices, etc. Damages are estimated based on distance to potential victims, weather, season, protective measures taken, etc. Emissions taxes are then based on estimated emissions and damages.

Marketable emissions permits are tradable rights to engage in environmentally damaging activities. Regulators determine the allowable amount of the activity, and an appropriate number of permits are allocated to agents, who may then buy or sell the permits. The allowable externality level is thereby achieved in an efficient manner. Permit systems can achieve outcomes as efficient as an emissions tax system. However, marketable emissions permit systems also have practical drawbacks. It is difficult to decide on an equitable initial allocation of permits, and to monitor compliance. In addition, markets for emissions permits may not be competitive if one or a few market participants control a large share of the permits.

Taxes on Agricultural Outputs or Inputs

Due to the difficulties involved in measuring and monitoring emissions and establishing emission tax or marketable emissions permit systems, policymakers may try to deter externalities indirectly through taxes on agricultural outputs or inputs. Such indirect control measures have several drawbacks because they fail to "target" the externality itself. For example, output taxes create incentives to reduce agricultural output, but the production of agricultural output, per se, is not the cause of externalities. Alternative methods may exist to produce the same level of output with lower levels of externalities. Output taxes provide no incentives to find alternative production methods. Another problem associated with output taxes is that the externalities generated per unit of output may be very different across agents. In that case, the efficient tax rate varies across agents. For administrative convenience, however, the tax rate is almost always the same across agents. A uniform output tax rate is inefficient because it does not allocate the strongest incentives to reduce pollution to the worst polluters.

Although input taxes, such as a tax per unit of fertilizer or pesticide use, may address externalities more directly than output taxes, their use also entails targeting problems. As is the case for output taxes, the externalities generated per unit of input may differ across agents. However, a uniform tax rate is easier to administer. In addition, some studies suggest that the price elasticity of fertilizer use, for example, is relatively low, so that a fertilizer tax would not affect fertilizer use—or the magnitude of associated externalities—to a great extent. A final problem with input taxes is that some inputs, such as manure fertilizer, may not be purchased; this would present additional difficulties for tax administration.

Deposit-refund Systems

Deposit-refund systems require that a deposit be paid on potentially polluting products, to be refunded upon return of the products or proof of nonpolluting use. Most agricultural externality problems do not seem amenable to deposit-refund systems because most purchased inputs are incorporated into the product (i.e., fertilizers), destroyed by the environment (i.e., pesticides), or so diffused in the environment as to make their collection prohibitively expensive. However, such a system might be useful to ensure proper disposal of unused pesticides and pesticide containers.

Cross-compliance Restrictions

Cross-compliance restrictions require that a producer engage in, or refrain from, specified activities in order to be eligible for other government programs, such as income support programs. However, it may be difficult to reconcile the objectives of a pollution control program with the objectives of a linked program. For example, an erosion control program may prohibit production on highly erodible soils as a requirement for price support payments, while the goal of the price support payment program is to maintain income levels on low income farms. If most highly erodible soils are found on low income farms, then erosion control through cross-compliance could be at odds with the goal of income maintenance.

3.5 Existing and proposed internalization policies

In this section we review existing and proposed policies to internalize agricultural externalities in industrialized and developing countries. After a brief overview of recent internalization initiatives at the international level, we close with a summary of policy proposals and recommendations from several sources.

National Policies — Industrialized Countries

Dosi (1992) examines policies aimed at controlling NPS pollution in the U.S., EEC, and Italy. Section 208 of the 1972 U.S. Federal Water Pollution Control Act (renamed the

Clean Water Act in 1977) required each state to formulate a plan to identify areas with "substantial water quality problems" and to propose suitable solutions. "Prior to the area-wide water quality management process defined in Section 208. . . , most nonpoint source programs could be considered [only] research" (Vigon, 1985). However, in general, states faced no requirement or incentive to implement their Section 208 plans. The 1987 rewrite of the Clean Water Act required (under Section 319) states to submit to the EPA an assessment report and a management plan for controlling NPS pollution. States were further required to obtain legal authority and identify funding to implement the plan. The only sanction for states which refused to do so denied them federal funds to finance the management plan they had not implemented! The EPA was forced to conclude that, although decentralization of NPS regulation is desirable, voluntary programs without sanctions would not achieve environmental quality goals.

The U.S. has other federal laws which affect NPS pollution. The Safe Drinking Water Act requires that states submit public water wellhead protection program plans to the EPA. The Coastal Zone Management Act of 1972 was amended in 1990 to require states to submit Coastal Nonpoint Pollution Control Program plans to the EPA and the National Oceanic and Atmospheric Administration. But again, the only penalty for failing to implement these programs is denial of federal cost-share funds. The Federal Insecticide, Fungicide, and Rōdenticide Act prohibits "any legal use of any pesticide which concentrates in processed food and is shown to present cancer risk." There has been no move to apply this rule to pesticides which concentrate in water. The Soil and Water Conservation Act of 1977 requires that the USDA periodically update a National Program for Conservation of Soil and Water. The 1989 update calls for voluntary programs to address both on- and off-site damages associated with soil erosion and NPS contamination of surface and groundwaters.

The 1985 U.S. Food Security Act established several programs affecting NPS pollution. The Conservation Compliance Program requires that farmers develop and fully implement farm conservation plans by 1995 or lose access to federal farm program benefits. The Sodbuster Program prohibits conversion of highly erodible land to agricultural production just as the Swampbuster Program prohibits the conversion of wetlands; violation of the provisions of either program results in the loss of many federal farm program benefits. The Conservation Reserve Program pays farmers to remove highly erodible land from agricultural production for 10 years and to plant it with groundcover. There is debate over the definition of highly erodible land: is it land with high erosion rates or land where erosion causes high levels of environmental damage? A Nonpoint Source Index that would account for proximity to surface water bodies as well as gross erosion potential has been proposed. The U.S. Wetlands Reserve Program authorizes retirement of up to one million acres of farmland for 30 years or more. The Water Quality Incentives Program authorizes incentive payments and cost share assistance for farm management plans that protect water quality and improve wildlife habitat. The Integrated Farm Management program allows 20% of base acreage to be planted to resource-conserving crops while farmers collect deficiency payments as if they were planting cash crops.

In 1988 the EC Commission passed a proposal (COM(88)708) regarding "measures relative to the protection of fresh, coastal, and marine waters from pollution due to nitrates deriving from nonpoint sources." Dosi (1992) considers this the first official EC document to specifically target "a precisely identified sub-set of NPS pollution problems." EC countries were required to identify vulnerable areas, regulate the use of animal waste and the distribution of chemical fertilizers in these areas, and register the quantities of animal and chemical nitrogen used. Voluntary compliance was allowed only in nonvulnerable areas. The Commission subsequently weakened this proposal with Directive 676/1991, which allowed several provisions to be "at the farmers' discretion" and eliminated nitrogen use registration requirements.

The EC has also implemented a series of set-aside programs since 1988. These focus on reducing crop surpluses and, unlike U.S. set-aside programs, do not have provisions for targeting NPS problems. However, EC Regulation No. 2078 outlines a program of subsidies for farmers who commit to specified conservation practices, including fertilizer or pesticide reduction, grazing density reduction, and leaving land fallow, for a minimum of 5 years.

Italy passed Act No. 319 (the "Merli Law") to protect surface and groundwaters from pollution in 1976. This Act instituted a system of discharge permits, established standards for effluents, and began a system of charges for activities causing discharges. The focus on "discharges" rather than ambient quality standards, and the intent to rely on structural devices as a primary means to achieve control, limited the effectiveness of this legislation for NPS pollution control. In 1979 Law No. 659 established a committee which found that the Merli Law should not be applied to farms that do not produce "terminal discharges." However, in part to conform to EC directives, several recent laws and decrees have established conservation areas (Decree 236/1988) around springs, catchment points, and aquifer recharge areas where some agricultural activities (i.e., application of pesticides or fertilizers) are prohibited. The newer laws emphasize ambient quality standards (Decrees 235/1992 and

16/1990) in regard to nitrogen fertilizer and herbicide contamination of water supplies destined for human consumption.

In 1987 the Western Australian government created the Integrated Catchment Management (ICM) Policy Group to develop a strategy to coordinate efforts to reduce and manage environmental impacts from land use (Wallis and Robinson, 1991). The ICM process there: 1) determines the boundaries of catchment areas; 2) sets environmental limits by determining the assimilative capacity of each catchment; 3) takes into account community desires in determining the best uses for land and resources in the catchment; and 4) helps communities to develop strategies ensure that the assimilative capacity is not exceeded.

Both Japan and Korea continue to rely primarily on command and control regulations (OECD, 1993a). In countries where a small number of very large firms account for a sizable share of industrial output and related industrial pollution, an approach targeting the worst offenders can be quite effective and monitoring costs are relatively low. Although industrialized East Asian countries may have relatively low levels of policy-induced price distortion compared to many LDCs, they may employ some pricing policies which undermine environmental objectives (e.g., Korea has fertilizer subsidies). On the other hand, Korea has also introduced a deposit-refund system for a number of products, such as cans and bottles, pesticide containers, batteries, and tires, which contribute to waste disposal problems.

The former Soviet Union faces institutional and administrative problems in introducing water and wind erosion control measures because private property rights are difficult to delineate (Golitsyn, 1992). Where erosion measures have been fully implemented, production has doubled or even tripled. The disintegration of the country has also delayed the mass production of machinery designed to reduce soil compaction. Formulation and implementation of effective agricultural externality policy in this region is predicated upon the creation of markets and credible government agencies.

The United Nations (1992) reports that environmental costs related to pollution are normally not recognized. It calls for a proper value to be placed on the services provided by the environment, since degradation often results because the environment is treated as a zero-priced resource. Improved accounting should reflect proper valuation of the natural resources, both as factors of production and as sources of waste absorption. Ahmad et al. (1989) note that there are several controversial issues concerning national income accounting as currently practiced; with respect to environmental and natural resource issues, the two outstanding issues are the treatment of environmental protection costs and the treatment of natural resource depletion.

Peskin and Lutz (1990) survey resource and environmental accounting in industrialized countries; they suggest that natural resource accounts ought to be separable additions to existing national accounts. The U.S. Department of Commerce (1994a, 1994b) provides an overview of the environmental satellite accounts for the U.S. (and a long-term plan to implement the framework); it also presents the results of such an analysis for the U.S. mineral resource sector.

<u>National Policies — Developing Countries</u>

<u>Asia</u>

Taiwan and Thailand appear more inclined to experiment with the use of economic instruments than do Japan and Korea (OECD, 1993a). Perhaps one reason for this is that Taiwan and Thailand have many more small and medium-sized geographically dispersed enterprises. A straight command and control approach would not be practicable under these circumstances, although both countries do have a basic regulatory framework which defines environmental quality standards. Taiwan and Thailand are actively studying the introduction of pollution taxes. In 1991 the Taiwanese government passed an Air Pollution Control Act which allows for a system of emission charges; a similar system of levies is being considered for water pollution. Bangkok is considering a pollution tax. Subsidies on pollution control investments or on less-polluting inputs also are in place. For instance, the Thai Ministry of Finance discounts the standard tariff on imported capital equipment for end of pipe waste treatment technology.

In establishing a basic regulatory framework, the Indonesian government is concentrating on building up monitoring and enforcement capabilities (OECD, 1993a). Indonesia may assign a less important role to incentive instruments as its environmental management system has been patterned after Canada's, which remains one of command and control. For example, the pollution control agreements are part of a tightly focused program to clean up the most heavily polluted rivers. Firms with the largest pollution loads were asked to draw up pollution abatement plans. Although not legally binding, the abatement agreements have been effective in deterring polluters. Aware that reform of existing pesticide subsidies could yield both environmental and economic benefits, the Indonesian government recently reduced from 82 to 40% the retail subsidy of pesticides. This reduction, combined with a ban on the use of 57 pesticides and the introduction of an integrated pest management system, has helped avert disaster. The Indonesian Ministry of Population and Environment has recently announced an import tax reprieve for waste water treatment equipment.

Chapman (1990) finds that the Indonesian government's agricultural pricing and subsidy policies contribute to environmental degradation by encouraging inappropriate land use. Rigid import controls and a heavily protected domestic pricing structure may provide indirect disincentives to soil conservation. As the average returns to highly commercialized and input-intensive crops such as vegetables increase, share tenancy and absentee ownership become more common. This can reduce the incentive for long-term investments in improved land management if tenancy arrangements are insecure and if the objective of absentee owners is short-term profit maximization or land speculation. The increased profitability of vegetable crops also encourages farmers to cultivate on steeply sloped volcanic soils, where water run-off and soil erosion are greater.

Repetto, et al. (1989) apply resource accounting to natural resources in Indonesia. Their study concentrates on the depletion of those natural resources that generate marketed output (oil, timber, top soil). They estimate harvesting, deforestation, and degradation net of regrowth for forestry, and suggest that it be treated like depreciation of man-made assets. That is, they propose reducing the NDP by the estimated depletion.

Magrath and Arens (1989) estimate the cost of soil erosion in Java at $350 to $415 million annually, which is slightly less than 0.5% of GDP. Khalid and Braden (1993) discuss Malaysia's restrictions on pollution from palm oil manufacturing residues. They review the effectiveness and cost of the regulations and calculate the negative producer welfare effects from different BOD levels. Peskin and DeLosangeles (1994) provide an overview of a current project to develop environmental and natural resource accounts in the Philippines. This paper also provides some general discussion on System of National Accounts (SNA) and presents a summary of accounting approaches.

<u>Central and South America</u>

El Salvador and Costa Rica have a number of old laws controlling pesticide regulation, soil conservation practices, protection of soil and water resources, and the introduction of new coffee plant varieties that might influence the environment (Segura and Reynolds, 1993). Fines are very low, and these laws are only weakly enforced. Water is much more expensive in El Salvador than in Costa Rica, and processors must pay to dump processed water into rivers. As a result, coffee processing uses less water in El Salvador, much of the processed water is treated before it is discharged, and groundwater pollution is less prevalent than in Costa Rica. El Salvador is considering the implementation of the International Code of Conduct for the Distribution and Use of Pesticides. Costa Rica has a new policy aimed at eliminating 80% of organic discharge from coffee processing plants over five years through subsidized loans from the Inter-American Development Bank and the Banco de Costa Rica. Research is currently underway in the areas of mixed-species cropping, soil conservation, integrated pest management, organic farming techniques, and the use of coffee processing residues as fertilizer. International agencies now require environmental impact assessments, including economic assessments of environmental damages, for these countries to qualify for loans. However, it is widely believed that influential groups may be finding ways to circumvent these requirements. Solorzano et al. (1991) discuss the national income accounts of Costa Rica. They include estimates of depreciation values for soil, timber, and fisheries.

Swezey and Murray (1986) review pesticide policy in Nicaragua. Nicaragua's heavy reliance on chemical technology is rooted in the production of cotton, a mainstay of the nation's economy. With help from the U.S. Department of Agriculture and the Food and Agriculture Organization of the United Nations (FAO), a group of Nicaraguan technicians laid the groundwork in the late 1960s and early 1970s for a comprehensive Integrated Pest Management program. It was designed to make maximum use of naturally-occurring insect controls, using biological, environmental, cultural, and legal methods in a complementary fashion. The Nicaraguan government established some of the most innovative regulations to control pesticide abuse ever introduced in Latin America (Faber, 1993).

Although current environmental policies in Brazil include pesticide registration, pesticide labeling, and the environmental licensing of polluting industries, actual fines for polluting are very small. In the mid-1960s, the Brazilian government launched an agricultural credit program that restricted credit to areas "agroecologically apt for coffee" and required contour planting practices, in addition to subsidizing inputs (May, 1993). Plantings from this period demonstrated reduced soil erosion. With trade liberalization, a relative decline in product prices, and the recession of the early 1990's, Brazilian coffee producers have adjusted pesticide use to levels even below those recommended for control of principal pests and diseases. There are no environmental policies for the coffee primary processing sector, it does not generate much pollution. In the coffee secondary processing sector, fairly rigid technology-based regulations have led to the widespread adoption of protective equipment, and even to the export of such equipment to the EC. In cocoa, environmental policies protecting the remnants of the Atlantic Forest ecosystem are failing due to lack of government coordination and enforcement capacity. In both the coffee and the cocoa sectors, subsidized credit or minimum price guarantees may reinforce soil exhaustion and excessive pesticide application.

Mahar (1989) discusses government policies and deforestation in Brazil's Amazon Region. Early settlers in the Rondonia region engaged in environmentally-unsound farming practices and deforestation. Recognition of the growing problems in Rondonia led to a government program to reduce forest clearance on land without long-term productive potential and to promote adoption of sustainable farming systems based on tree crops. The program has not worked because: 1) subsidized credit for the inputs necessary for risky tree cultivation has not been available in sufficient quantities; 2) the government has not been able to enforce the "50% rule," prohibiting settlers from clearing more than half their land; 3) the rural land tax structure, where tax rates decrease as utilization increases; 4) the government accepts deforestation as evidence of land improvement; and 5) land speculation is rampant, and pasture is the least expensive way to holding land while it appreciates.

May (1993) notes that Brazil is considering a number of environmental policies including: 1) increased emissions charges or taxes; 2) strengthening regulatory and enforcement institutions; 3) green labeling, or environmental certification of chocolate products; 4) a precautionary "Polluter Pays Principle", which would require potential polluters to purchase ex ante insurance against future environmental damages; 5) financing new technology adoption; and 6) promoting integrated pest management.

Africa

Chapman (1990) finds that inadequate investment in research and extension, governmental interventions that keep food prices artificially low, and formal and informal tenurial regimes often discourage the adoption of conservation measures, encourage excessive land clearing, or both. In the Sahelo-Sudania and Sudanian climatic zones, the regional governments maintain low food prices for the benefit of urban consumers and ignore the marketing bottlenecks responsible for price instability and the farm-gate price collapse at harvest time. Because agricultural research and extension are not strong, incentives to adopt high-yield sustainable crop production systems are weak, and farmers opt for extensive production on fragile lands. Some property arrangements discourage environmental conservation. Under the communal tenure regimes that prevail in the Sahel, a family wishing to plant crops is entitled to temporary use of a parcel. However, planting trees or even perennial crops is often regarded as an attempt to assert permanent individual rights in communal land. Under these circumstances, there is an institutional constraint on afforestation.

Governments in equatorial Africa also accelerate resource degradation by attempting to supplant local tenure regimes. Ignoring the distinction between common property and open access, they have failed to offer legal mechanisms for protecting communal land rights. Instead, attempts are often made to convert common properties into government lands or private properties, even though the public sector's capacity to manage its resources and the legal infrastructure needed to enforce private tenure are both poorly developed. Weakening traditional property arrangements without providing a viable institutional alternative reduces the incentive for forest dwellers to conserve natural resources.

As a final note on this section, Lutz, et al. (1990) discuss environmental accounting issues from the perspective of developing countries.

International Initiatives

Dawkins et al. (1994) review recent internalization initiatives at the international level. They examine two contemporary initiatives to address the lack of full-cost pricing for agricultural products under the GATT. The first proposes 'anti-dumping laws', defined as the export of goods at prices below the cost of production in Article 6 of the pre-Uruguay Round of GATT. The second, newer approach involves a formula called the 'Aggregate Measure of Support' or AMS. All taxpayer-paid costs of production for agricultural products have been identified and listed with a specified financial value. "Everything from easily quantified water and fertilizer subsidies to more complex items such as the value of government-paid maintenance of inland waterways are included. . . . in June 1994, the GATT hosted its first symposium with non-governmental organizations to consider the internalization of costs as an environmental measure in trade policy." In addition, the OECD has created two working groups to study the issue, one to consider the impacts of economic instruments and environmental subsidies in trade policy, the other to look at the mechanics of life-cycle analysis.

A Review of Internalization Policy Recommendations

Ribaudo (1986) looks at off-site vs. on-site benefits of soil erosion prevention programs in the U.S. He finds that focusing on on-site criteria rather than off-site could lead to inefficient allocation of soil conservation funding. Dosi (1992) provides a list of recommendations for policy development: 1) promote public awareness of NPS problems; 2) develop mechanisms (e.g., bio-physical models, to identify polluters other than traditional expensive/infeasible monitoring at the emission source; 3) develop pollution prevention programs and provide appropriate incentives for participation—voluntary programs are not sufficient.

Peskin (1986) suggests that, rather than concentrating on cropland controls as the only practical policy target, it might be worthwhile to investigate indirect control strategies for difficult-to-control nonpoint sources. In certain regions upstream interception of pollutants, using small reservoirs and holding ponds, may be a cost-effective approach for any NPS, including cropland. While this approach has been implemented, its cost-effectiveness has not yet been thoroughly explored. Braden and Lovejoy (1990) discuss a three-part policy package to address issues involving agriculture and water quality: 1) a set of input taxes designed to reduce pesticide and fertilizer use and to raise revenue; 2) mandatory regulation of soil erosion targeted toward water quality, which could be coupled with cost-sharing provisions financed by input taxes; and 3) regulation of pesticide and fertilizer use and explicit farmer liability for remaining groundwater contamination, with the possibility of purchasing pollution liability insurance. Although such a package is imperfect, it provides an example of how a variety of policy instruments, based on both incentives and regulation, could be combined in an attempt to balance policy concerns.

Shortle and Dunn (1986) examine the relative expected efficiency (net benefits) of four general strategies suggested for achieving agricultural nonpoint pollution abatement. Referring to the flow of pollutants from a farm as runoff, the four strategies considered are: 1) economic incentives applied to estimated runoff (e.g., a tax on estimated soil loss); 2) estimated runoff standard (e.g., estimated soil loss standard); 3) economic incentives applied to farm management practices (e.g., taxes on nutrient applications); and 4) farm management practice standards (e.g., required use of non-till). Setting aside policy transaction costs, the principal result of this analysis is that an appropriately specified management practice incentive should generally outperform estimated runoff standards, estimated runoff incentives, and management practice standards for reducing agricultural nonpoint pollution.

Letson et al. (1993) discuss methodological issues in PS/NPS trading and the feasibility of P/NPS trading in coastal watersheds in the U.S. A set of simple screening rules reveals that 10% of coastal watersheds have significant contributions of loadings from both point and nonpoint sources. These results suggest that PS/NPS trading is more likely to work in a small number of coastal watersheds rather than as a means for bringing NPS in coastal watersheds under national control.

Shortle (1987) examines the possible use of information on the relative marginal costs of point and NPS pollution abatement to assess the efficiency implications of shifting more of the burden for water pollution control to nonpoint sources. Although some of the specific results of this analysis are contingent upon the underlying assumptions, two are pertinent. First, the conclusion that the marginal costs of point source and expected nonpoint source abatement will differ in a balanced allocation when the pollutants are perfect substitutes is due to the uncertain effect of resource allocation on nonpoint pollution loads. Second, whether the pollutants are perfect substitutes or not, the exact relationship between the marginal costs of point source and expected nonpoint source abatement in a balanced allocation cannot be determined without a well-defined damage cost function.

Southgate (1988) proposes that the solution to many LDC land degradation problems involves action by small farmers who often farm their fragile land in a way that does not conserve soil. In part, farmers' reluctance to adopt conservation measures is a consequence of distorted price signals. In addition, the suboptimal use and management of natural resources is explained largely by the tenure regime they face. They rarely possess "unattenuated" private property rights in the resource they use and often live where traditional systems of common property tenure are breaking down or where open access resources are available. A change in market forces or government policies that results in an increase or decrease in labor's opportunity cost affects small farmers' decisions regarding the use and management of land. In addition, other price signals such as interest rate, commodity prices, exchange rates, and prices for non-labor inputs to agriculture, affect small farmers' decisions and may be used as incentives for proper land management.

Kox (1991) has proposed a new International Coffee Agreement that would establish a tax on coffee "of no less than 1% of the cost of coffee in international markets. These economic resources would go directly to producing countries where one institution or committee would be in charge of distributing them according to environmental national priorities."

3.6 Discussion and Conclusions

In reviewing *extensification damages* we find that, although qualitative descriptions of environmental damages are available for several regions, quantitative estimates are limited to a small number of specific case study areas. Quantification of *intensification damages* is somewhat further advanced, especially the on-site damages of soil erosion to crop productivity and the off-site damages of sedimentation to reservoirs. However, other on-site damages (pest resistance and beneficial insect destruction) and off-site damages (pesticide effects on fish and wildlife) await quantification.

In the U.S. educational, voluntary, and cost-sharing programs have been somewhat successful in curbing soil erosion, but such programs have not successfully addressed other types of NPS pollution. This probably reflects the fact that farmers have private incentives to reduce soil erosion (i.e., maintaining soil productivity), but have no similar private incentives to combat other types of NPS pollution.

In many regions of the world, the key impediments to the solution of agricultural externality problems are economic and institutional rather than technological. Environmental damages could be reduced greatly through the application of appropriate economic policies and institutional reforms; no major new technological advances would be required. Unfortunately, most national and international policies attempting to address the problem of environmental damages caused by agricultural activities could be described as "projects." They are very limited in scope, do not consider the interaction of the project problem with other economic markets and policies, are incorrectly targeted to reduce crop output or acres harvested rather than to reduce environmental damages, and are designed to terminate after meeting narrow goals within fixed project budgets and time horizons. In contrast, appropriate internalization policies should have a broad-based, general-equilibrium design. Features of such a program are described below.

Internalization policies must be broad in scope to *recognize the trade-offs which exist* in reducing off-site environmental damages. For example, Faeth (1991) reports that Crutchfield (1987) estimated that "the establishment of a permanent vegetative cover reduces nitrogen in surface runoff by 90 percent, but increases nitrogen in [groundwater] leachate by 26 percent" in one region of the U.S. Internalization policies also should have a general equilibrium nature, taking into account interactions with other economic markets and policies. For example, the agricultural market distortions in many countries alter the relative prices of agricultural outputs and inputs (price supports in the U.S. and EC, pesticide subsidies in the Philippines and India). These distortions can exacerbate environmental damages through altering crop production methods and input choices. Under distorted market conditions, internalization mechanisms must be more severe to achieve environmental policy goals because they must correct both the market distortion and the environmental damage externality.

Whenever possible, attempts to internalize environmental damages should target the actual damages themselves rather than some proxy variable. This is especially relevant in situations where the quality and magnitude of environmental damages associated with a given level of crop production depend on production methods. For example, Faeth (1991) discusses two case studies in the U.S. where conventional farming systems are compared to alternative methods. In one of the case study areas, the alternative production methods increased yield while reducing environmental damages. Internalization policies which target environmental damages instead of crop production allow these win-win outcomes. Targeting environmental damages also provides incentives to develop the new, alternative cropping methods which can maintain yields while reducing damages.

The design of internalization mechanisms should take into account the dynamic nature of some environmental problems. For example, groundwater depletion is a common dynamic problem in irrigated regions. The common property nature of the groundwater pool often results in inefficient, accelerated depletion. Soil erosion is another example of a dynamic problem. The benefits of reducing erosion rates are higher at lower levels of erosion (Anderson, 1987). At higher levels of erosion, the value of maintaining or enhancing the fertility of the significantly degraded soil is much less, so it is better to protect soils earlier rather than later.

In theory, it is necessary to know the marginal environmental damages associated with an activity in order to set efficient internalization charges. This review points out that there are limited data on the *average* environmental damages associated with agricultural activities (much less the marginal damages), especially for developing countries. Even if marginal damage data were available, they would vary by geographical region, year, season, and even time of day. Relationships between marginal environmental damages and agricultural activities are often nonlinear, resulting in sudden surprises and dashed expectations. Researchers should give some thought to establishing a global system to collect, update, and disseminate estimates of environmental damages efficiently and quickly, in order to respond rapidly and *adaptively* to changing environmental conditions.

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Abelson (1979)
- The benefits of soil conservation project are increased livestock output, flood mitigation, improved water quality, improved amenities.
- The timing of the implementation of the project is important.
- Bojo et al.(1990) pointed out that if the project is financed through general tax revenues, the associated deadweight losses would be added to the costs of the project.

Akande (1993)
- Review the effects of producing and processing cocoa on the environment.
- Cocoa is a labor intensive industry in Nigeria, and capital input occurs mainly in the form of pesticides.
- Pesticides are highly subsidized by the government.

Anderson (1987)
- Discuss the destruction of trees in woodland and farms.
- The consequences are decline in farm tree stocking, decline in soil fertility, degradation of forest reserves.
- The program focuses on the designation of shelterbelt, which improved the environment.
- The benefit of program depends on the timing of implementation.

Bishop and Allen (1989)
- Focus on the on-site costs of soil erosion, especially the loss of fertility of the soil and the resulting loss in agricultural product.
- The present value of net farm income loss due to one year of soil loss is 3.95% of agricultural GDP and 1.54% of total GDP in Mali.

Bojo (1990)
- Discuss the environmental degradation and proposed program in Lesotho.
- The project encourages the use of inorganic fertilizer and hybrid seed varieties as well as the rehabilitation and construction of waterway and drainage system.

Clarke et al. (1985)
- Present estimates of costs of soil erosion in the U.S., including sedimentation and flooding damages, lost recreational opportunities, instream damages to fisheries, and degraded water conveyance facilities.
- Total damage costs attributed to cropland is estimated to be 2.2 billion per year in 1980 dollars.

Cruz et al. (1988)
- Provide suggestions for how to assess the economic impacts of soil erosion focusing on watershed.

Dada (1985)
- Discuss on-site and off-site costs resulting from nonpoint source pollution in U.S.

Faeth (1993)
- Present estimates of soil depreciation cost.
- Good case studies with comparative farm budgets across several alternative methods of production.
- It provides an expected utility model incorporating health costs of pesticides exposure for rice farmers in the Philippines.

Faeth et al. (1991)
- Develop estimates of Net Farm Income and Net Economic Value to Society under a variety of government policy scenarios in two farming regions of the U.S., Nebraska and Pennsylvania.
- The principal finding is that where erosion-prone soils are causing substantial environmental demage both on and off the farm, resource-conserving production systems are economically superior.
- Point out that U.S. agricultural policies carry with them serious unintended environmental costs.

Finney and Western (1986)
- Explain the integrated environmental program for the island of Palawan commissioned by government and EEC.
- The proposed program consisted of : protection of upland forests, increased regulation of commercial logging, stabilization of agricultural systems, establishment of parks and reserves, and infrastructure investments.
- Present the expected benefits of the program: agricultural benefit, infrastructure benefits, tourism benefit, mangrove forest protection benefit, and coral reef protection benefit.

Golitsyn (1992)
- Discuss the states of environmental damages in some regions of USSR.

Khalid and Braden (1993)
- Discuss the effectiveness and costs of government regulations.
- Provide estimates of the negative producer welfare effects from various levels of BOD standards.

Kim and Dixon (1986)
- Discuss the damage in the environment due to the inadequate soil management technique in Korea.
- Suggest two alternative methods of avoiding soil erosion : the prevailing method which involves replacing soil and soil nutrients in the uplands and clearing silted paddies in the lowlands, and the prevention method which involves mulching the upland areas.

Mahar (1989)

- Discuss the causes of deforestation and suggest environmental program in Brazil's Amazon region.
- The suggested program is to reduce forest clearance on land without long-term productive potential and to promote a more widespread adoption of sustainable farming systems based on tree crops.

May (1993)

- Discuss the environmental effects of coffee and cocoa production and processing.
- By pointing out ineffectiveness of current policies, it provides potential environmental policies.

Pagiola (1994)

- Discuss the returns to soil conservation policies.
- It concludes that given the low cost of production, the investment in soil conservation is not repaid until the 48th year.

Segura and Reynolds (1993)

- Discuss the environmental impacts of discharge of untreated water to rivers in coffee processing industry.
- Discuss the current and proposed environmental policies.

Sfeir-Younis and Dragun (1993)

- Provide estimates of soil erosion rates and causes and effects of this erosion in LDC.
- Major causes are shifting cultivation, illegal encroachment on forests by subsistence farmers, over-exploitation of common property, settlement of land for commercial agriculture, and inappropriate forest harvesting techniques.
- Major effects are flooding, siltation of waterways, and destruction of marine ecosystems.

Solorzano (1991)

- Calculate the value of loss in soil productivity due to soil erosion.

Southgate (1988)

- Explores some of the causes for soil erosion on small subsistence farms in LDC.
- Tenure regimes, some agricultural development strategies as well as distorted price signals induce development of fragile hinterlands and can discourage the use of conservation measures.

Southgate and Macke (1989)

- Present a model for estimating the off-site benefits of soil conservation project on a hydroelectric watershed, and applies it to a project to reduce erosion in a hydroelectric watershed.

Southgate et al. (1984)

- Provide figures on the net present value of soil conservation project on private lands.

Witte et al. (1993)

- Discuss the damages from the fertilizer and pesticides use in rice production.

4. Analysis of Internalization Using a Static Trade Model

4.1 Introduction

Free trade is often seen as an impediment to the adoption of internalization policies, because trade encourages production to shift to regions where producers do not internalize environmental costs. This makes it harder for a single country to pursue these policies. The trade effects need to be considered when evaluating the benefits of internalization. We discussed this issue in Chapter 2.2, where we illustrated plausible trade effects using a single commodity partial equilibrium model. For a range of parameter values, we showed that the change in market share and the relocation of production, following an increase in costs in one producing region, are likely to be quite small. The effect on export revenues can be positive or negative, depending on the elasticity of excess demand facing the country that internalizes. The model we used provides some information on likely order of magnitudes, but it is not sufficiently detailed to provide estimates of changes for actual commodities and actual policies.

This chapter illustrates how to model in greater detail the trade effects of internalization policies. The model here and in Chapter 3.2 share two characteristics. Both are static; the only way they can account for long-run effects is to increase the elasticities. Both are partial equilibrium; they ignore income effects. The model in this chapter, however, allows us to study internalization policies that affect several commodities. In our previous model, we took output level as a proxy for environmental damage, although we recognized that the correlation between the two may not be very high. In the model here, we assume that environmental damage is more likely to be correlated with a particular input, fertilizer, which is used in the production of several commodities. This input causes the markets for the several commodities to be linked, even if there is zero cross-price elasticity of demand. For example, a tax on the output of one commodity alters its demand for fertilizer, changes the price of fertilizer, and therefor changes the supply functions of other commodities. A fertilizer tax has obvious effects on all commodities. The model in this section enables us to study these kinds of interactions among commodity markets.

We use coffee, cotton, and sugar to illustrate the techniques, and to indicate what type of results such a model is likely to produce. We also discuss the kind of information we need in order to make the model more useful. Section 4.2 presents a synopsis of world markets for our three commodities. Section 4.3 reviews existing trade models for these commodities. Section 4.4 illustrates the trade effects of an input tax (for fertilizer) and of commodity taxes, for both the cases where these taxes are imposed unilaterally, and multilaterally. In Section 4.5 we discuss the usefulness, for the purpose of policy analysis, of this sort of model, and we suggest directions for future research.

4.2 Description of the Coffee, Sugar and Cotton Markets

We describe the markets for coffee, sugar and cotton in this section, before turning to modelling issues. We begin with data which summarizes and compares the three commodity markets, and we then turn to the individual descriptions of each market.

The information we summarize gives the reader an idea of the inadequacy of standard trade models, including the one we use below. That model consists of supply and demand relations in a competitive framework. From our description of the markets, it is clear the model excludes many important issues. For example, asymmetries in supply adjustment mean that a single supply elasticity may not be capable of describing supply response. Governments are important players in commodity markets, because domestic policies influence domestic supply and demand, and because international policies (such as preferential arrangements or International Commodity Agreements) alter world prices and trade flows. However, our model captures government involvement very imperfectly, and takes it as exogenous. Moreover, we see that changes in consumer taste, the introduction of new products, and diffusion of technology, may be important determinants of trade. These features are difficult to measure, and are largely absent from most trade models. Our summary of commodity markets provides a context which helpful in evaluating trade models.

Table 4.1 presents data for the coffee, sugar and cotton markets. All of these commodities are important in world trade. For each of these, LDCs account for a substantial portion of world production and trade. Coffee is an example of a commodity that is produced in the South and consumed in the North; for cotton and sugar, production and consumption in the two regions are more balanced. For the three commodities, the five largest producers account for between 40% and 76% of world production, and the five largest consumers account for between 40% and 60% of consumption. This represents a fairly high degree of concentration on both sides of the market. Real prices have fallen substantially over the past ten years for all commodities; this is particularly true for coffee. An index of stability, which is measures the absolute deviation between the actual price and its estimated trend, has

Table 4.1 Characteristics of the World Markets of Coffee, Sugar, and Cotton (1991)

Commodities / Characteristics	Coffee	Sugar	Cotton
Share of LDC in World Production (%)	99.98	76.64	80.29
Share of DC in World Consumption (%)	68.00	26.62	21.85
Share of LDC in World Exports (%)	92.17	64.01	58.48
Share of DC in World Imports (%)	87.04	32.38	37.37
Supply Concentration (5 largest producers)			
Concentration ratio (%)	55.17	40.02	76.13
HHI	0.08998	0.01674	0.14050
Demand Concentration (5 largest consumers)			
Concentration ratio[1] (%)	52.81	40.52	60.63
HHI[2]	0.06952	0.03717	0.08992
Instability Index[3]			
1983 ~ 1988	13.0	28.7	13.4
1988 ~ 1992	11.4	15.0	13.3
Growth Rate of Price[4] (%) (in constant 1980 dollars)[5]			
1983 ~ 1988	-8.7	-1.2	-12.5
1988 ~ 1992	-18.4	-6.5	-1.7

Note: Share data and concentration data are calculated based on quantity data from UNCTAD (1993). LDC includes CPN.

1 Concentration ratio = $\Sigma y_i / Y$, where y_i is each country's production (consumption), and Y is world total production (consumption). i = 1,...,5

2 Herschman-Herfindahl Index(HHI) = Σs_i^2, where s_i is share of the production (consumption) earnings in world total production (consumption). i = 1,...,5

3 Instability index = $1/N \, \Sigma \, \{|Y - Y_t| / Y_t\}$, where Y_t is the observed magnitude of variable (price), Y is the magnitude estimated by fitting an exponential trend to the observed value, N is the number of observations. Instability is measured as the percentage deviation of the variables concerned from their exponential trend levels for a given period.

4 The growth rate of price has been calculated using the formula:

$\log(p) = a + bt$, where p is the price index, and t is time.

5 Constant 1980 dollars : current dollars divided by the U.N. index of export unit value of manufactured goods exported by developed countries.

decreased slightly over the previous decade. The magnitude of this index is similar for the three commodities, for the late 80's and early 90's.

Coffee[6]

Coffee is one of the most important tropical commodities in international agricultural trade. Production and consumption are geographically separated. Production occurs in tropical regions, whereas consumption is concentrated in Western Europe, North America and Japan. Many exporting countries are heavily dependent on coffee for foreign exchange earnings. On the other hand, imports of coffee form a small share of the total value of imports of DCs.

Production: Coffee production is concentrated in LDCs because of ecological requirements. Random weather and the biennial bearing cycle of coffee trees lead to substantial yearly variations in world coffee production. Although Brazil's share of world production has been steadily eroding since World War II, Brazilian production fluctuations still dominate the world production cycle. Latin America is still the dominant producing region, with 67% of world production in 1991. Brazil ranks first with 25% of production and is followed by Colombia with 14%. Africa contributes 19% of world production; together these two areas account for about 86% of total world coffee production.

Consumption: Coffee consumption is concentrated in the DCs. In 1991, EC (32%), US (20%) and Japan (7%) accounted for more than half of world consumption. Per capita consumption in the US has shown a constant decline since the 1960's following the intro-duction of substitute drinks, and possibly due to health concerns. The growth of Japan's consumption is notable, where coffee is being substituted for tea. The share of Japan's consumption in world market rose from 1.6% in 1970 to 7% in 1991. About 20% of world coffee production is consumed in the producing countries, with Brazil accounting for half of the share.

Trade and price: Though the DCs do not produce coffee, the account for 7.8% of world coffee exports in 1991. Some DCs, especially Germany, import coffee beans from LDCs, transform them into roasted or instant coffee, and then re-export the finished good. In 1991, DCs accounted for 87% in world imports. Prices tended to be unstable. Due to the

[6] Data is from FAO (1992b, 92c) and Pieterse and Silvis (1988).

export quota system, neither production nor consumption were responsive to price changes. Prices fell sharply after the failure of the last International Coffee Agreement (ICA).

The International Coffee Agreement (ICA)[7]: The operation of the international coffee market was influenced by a succession of ICAs. The first agreement began in 1963, with the objectives: (i) ensuring adequate supplies of coffee at "fair" prices to consumers, (ii) providing markets for coffee at profitable prices to producers and, (iii) avoiding "excessive" fluctuations in the levels of world supplies, stocks, and prices (ICO 1983). The ICA was renewed in 1968, 1976, and 1983, with the same objectives. Export quotas were used from 1963 to 1973, from 1980 to 1986, and from 1987 to 1989. Despite the existence of the first goal, the ICA was generally viewed as a means of making transfers from consumers to producers.

The political goal of preventing the spread of "Castroism" is one explanation for US support of the ICA (Krasner 1973). Higher coffee prices would presumably enhance the economic prosperity and political stability of Latin American nations. The added cost to U.S. consumers was accepted as the price of meeting this objective. Reasons for European membership include support for former colonies in Africa and Asia. Thus, foreign policy and humanitarian motives can explain the long term participation of importing countries in the ICA.

Member exporters supplied 99% of world exports and member importers purchased about 90% of world imports. Member importing countries agreed to purchase coffee only from member exporting countries. A global export quota for members was divided into a fixed part which was allocated to the exporting countries as basic quotas, and into a variable part which was distributed according to the proportion of national stocks to the total stocks. Quotas were adjusted, depending on the relationship between world prices and the price range set under the Agreement.

There were, however, no restrictions on exports to non-member countries. Exporting countries with excess supply sold surplus stocks to the non-member market at large price discounts. The primary beneficiaries were East Bloc and oil exporting countries. Sales to the non-member market were regularly re-exported to member importers. Coffee traders and processors objected to this illicit trade. The price differential between the member and non-member markets emphasized the costs borne by member country consumers (Bohman 1991).

[7] Our discussions of ICA's is based on Akiyama and Varangis (1990), Bates and Contreras (1988), Pieterse and Silvis (1988), and especially Bohman (1991).

There is little consensus on either the true objectives or the effects of the ICAs. Some authors think that it raised prices, while others argue that it stabilized them; it may have done neither. The effect of the ICAs on export revenue was uncertain. It may have increased export price, while reducing quantity. In addition, the rent-seeking caused by the quota rents may have resulted be a welfare loss for exporters. Herrmann (1988) claims that "ICA is a price-raising agreement since it does not include a mechanism for lowering prices in boom periods." Gilbert (1987) shares this opinion, and concludes that the ICA was price-raising rather than price-stabilizing. Lord (1988) argues that the initial impact of ICA was to raise prices, which resulted in a larger world supply. Akiyama and Varangis (1990) conclude that member market prices in 1984 and 1986 were lower with the ICA than they would have been with free trade, since additional stocks caused by export quotas augmented supply when world production fell.

Negotiations to renew the last ICA foundered on two major issues: (i) The member importing nations objected to the large discounts at which coffee had been sold on the nonmember market, and wanted a system to end such discounts. (ii) The member nations which import mild or arabica coffees objected to the steady increase in the price of mild relative to robusta coffees, and wanted a redistribution of export quotas which would permit an increased supply of milds.

Sugar[8]

The world sugar price cycle contains long troughs followed by short, sharp peaks. This volatility can be explained by policies pursued in countries that insulate and subsidize domestic markets, especially in the OECD. For many countries trade is important for either production or consumption.

Production: World sugar production was 72 MMT in 1970 and increased at an average annual rate of 2.3%, reaching 112 MMT in 1991. Two reasons for this growth are (i) the operation of domestic sugar policies which insulate domestic markets, and (ii) large supply increases following the brief periods of high prices. Protectionist domestic policies are widespread in DCs. Many LDCs attempt to achieve self-sufficiency in sugar using expansionist domestic policies. Producers also appear to have acted under the belief that the

[8] This description is based on information in Lord and Barry (1990), Sturgiss et al. (1987), and OECD (1991).

price rises were the result of a surge in demand, rather than supply problems. This triggered off large investments in exporting countries, resulting in increased production. The top 10 producers accounted for about 60% of world sugar output; DCs accounted for about 23% of production in 1991.

Consumption: Global consumption, unlike production, is relatively steady from year to year, reflecting the stability of the human diet. Most variations in consumption from trend are due to stock changes. Population and income growth and the increased use of substitute sweeteners, mainly high fructose starch syrup (HFSS), are the leading causes of changes in consumption. In many DCs, the use of sweeteners has reached near-saturation levels. This fact, combined with slow population growth and typically high government controlled consumer prices, has led to a slow or stagnant growth in sugar demand. High price policies for sugar have stimulated the development of substitutes, such as HFSS and low-calorie sweeteners.

LDCs account for most of the recent increase in world sugar consumption, due to high rates of population growth and rising incomes. In countries with low per capita incomes, sugar consumption is responsive to income changes. Economic growth in LDCs is expected to result in increases in consumption in the future. The share of world consumption of the DCs dropped from 42% in 1970 to 26% in 1991.

Trade: Although sugar is among the most heavily traded agricultural commodities in the world, less than 30% of world production crosses national borders. Over 70% of world sugar output is consumed within the producing country, usually at government-regulated prices. Another part is exported under bilateral long-term arrangements at prearranged prices or under preferential terms. Only about 20% of production is freely traded in international markets, largely as a residual after domestic needs and preferential sales are satisfied.

Approximately one third of world sugar trade was conducted at pre-arranged prices during the 80's. Cuba's barter arrangements with the USSR and other centrally planned nations comprised 75% of its sugar exports. Nineteen LDCs exported 1.4 MMT of sugar to EC under the Lome Agreement, at the EC internal premium support price. The U.S. paid a premium price for its quota imports from a group of 40 exporters.

The top 10 sugar exporters in 1991 accounted for about 71% of world exports, while in 1970 the top 10 exporters accounted for only 55% of world exports. DCs increased their export market share from 17% in 1970 to 36% in 1991, and the share of imports of DCs decreased from 61% to 32%.

Price fluctuations: Sugar prices are among the most unstable in international trade. Even incremental changes in supply or shifts in government policy have large effects in the thin residual market. In periods of crop failure, governments temporarily restricted exports to meet domestic needs, thus intensifying the upward movement of the world price. In periods of bumper harvests when output exceeds domestic needs, exporting nations sometimes dump their surpluses on the world market, exerting downward pressure on the world price. Producers are able to maintain output because (i) previously high prices provide a reserve of funds, (ii) the true price to the producer is the result of a blend between the free market and the higher priced domestic and preferential trade markets, and (iii) governments intervene through income support programs.

There is a broad pattern of high prices for 1-2 years followed by a long period of low prices. Large, infrequent, investments in production, and government intervention contribute to the cycles. Sugar production responds rapidly to high prices but is much less elastic when prices fall. Rapid production increases bring down price spikes within 2 years, but high production levels tend to persist even at prices which are below the cost of production for many exporting countries.

The International Sugar Agreement (ISA): Three international sugar agreements were established from the 50's through the 80's; all used export quotas in an attempt to control exports and stocks. Their objectives were to raise the world sugar price and stabilize it within certain bounds. The ISAs did not succeed in keeping world prices within the specified range, due to the non-participation of the EC and high monitoring costs of enforcing export quotas.

Cotton[9]

Production: World cotton production increased at an average annual rate of 3.4% from 12.02 MMT in 1970 to 20.641 MMT in 1991. The share of production in the DCs remained approximately constant, the LDC share decreased slightly, and the share of

[9] Information for this section is based on UNCTAD (1992).

Centrally Planned Nations (CPNs) increased. Production is highly concentrated, with five countries accounting for 76% of the 1991 total. China was the world's largest producer (27% of world cotton production), followed by U.S. (18%).

Consumption: World consumption grew steadily, following growth in world population and increased per capita consumption in the LDCs and NCPNs. The share of DCs in world cotton consumption dropped from 33% in 1970 to 21% in 1991, while that of LDCs rose from 47% to 68%. The development and widespread use of synthetic fiber account for the change of consumption in DC. In the LDCs, the substitution of synthetic fibers has been limited by the rate of technology diffusion.

Trade and price: Although LDCs account for the bulk of world production, their share of exports is only slightly larger than that of the DCs. A strong income effect has increased LDC consumption, while the substitution effect has tended to decrease demand in the DCs. The US has a large impact of the market, with an export share in excess of 30%.

4.3 Review of Trade Models for Coffee, Sugar and Cotton

We now summarize previous attempts at estimating empirical trade models of our three commodities. Our ultimate objective is understand how to go about quantifying the relationship between internalization policies and international trade. An obvious preliminary step is see what is already known about the trade relations for specific commodities. There are three reasons for collecting this information. First, it provides us with a range of parameter estimates for a particular application. Second, we do not want to duplicate previous research. We think that existing empirical research should be exploited; more estimation of standard models is not a high research priority. Third, the review gives us a sense of the limits of empirical research.

The review indicates that there is little consensus regarding the magnitude of supply and demand elasticities. This is not surprising, since the various studies used different data sets and different models. It is important to know the extent of (or the lack of) robustness of the elasticity estimates.

In order to summarize of a large body of literature succinctly, we tabulate the elasticity estimates for the different commodities. Each table is preceded by a short discussion of the studies, which deals with both supply and demand elasticities. Each table is followed by a series of notes which give more details of the studies.

Coffee (Table 4.2)

Production of coffee is determined by the stock of trees and input use, such as fertilizer and labor. Coffee's long-term planting and harvesting cycle and is often interrupted by climatic factors. The lag between planting and the first mature yields is 4-7 years, depending on the type of coffee. Although production responds with a fairly long lag to a change in the market price, adjustment is rapid once it begins Lord (1991). Thus, the short-run supply elasticity of coffee is very low, while the long-run elasticity is fairly high. Lord's estimated supply elasticity is close to that of Adams and Behrman, but substantially lower than Hwa's (1985) estimate of 0.872 and Akiyama's (1982) estimate of 0.739. The supply elasticities estimated by Akiyama and Varangis (1989), Akiyama (1982), and Singh and De Vries (1977) are very different across regions. Singh and De Vries explanation is that in a country where agriculture is largely devoted to coffee cultivation, the elasticity tends to be low due to the lack of alternative sources of income.

The consumption of coffee in DCs is influenced by retail price and income. The demand elasticities are relatively stable both in the short-run and long run, ranging between -0.2 and -0.4. The world income elasticity is around 0.5 in Hwa (1985) and Akiyama (1982). The negative U.S. income elasticity in Okunade (1992) and Heien and Pompelli (1989) may be explained by increased health concerns. Japan's high income elasticity is consistent with a change in taste, as the coffee-drinking habit has taken hold since the 1980s.

Cotton (Table 4.3)

Adams and Behrman (1976) explain that cotton production in LDCs and CPNs is principally from irrigated fields which require a long gestation period and a considerable investment, whereas in the U.S. cotton is produced largely without irrigation and is readily substitutable for other crops. Therefore, their estimate of US cotton supply elasticity is higher than that of LDCs and CPNs. Duffy et al. (1987) estimate U.S. short-run supply elasticity and obtain a result similar to Monke and Taylor (1985)'s estimate of world supply elasticity, approximately 0.37. However, the world long-run elasticity estimated by Monke and Taylor is much higher than Duffy et al.'s estimate of U.S. elasticity. This is not consistent with Adams and Behrman's explanation. Monke and Taylor account explicitly for quantitative control on international trade. They classified countries into price-responsive countries and nonresponsive countries, and estimated equations for 15 price-responsive countries. Since the burden of adjustment for world price changes falls on price-responsive countries, their estimate is higher than others'. According to Lord (1991), the estimate for the production relationship indicates that there is a 3 years lag before production adjusts to changes in prices.

There has been significant substitution toward the new synthetics since 1980s. In DCs, there is a negative time trend which reflects non-price aspects of the substitution toward synthetic fibers. Shui et al. (1993a) investigates the impact of technical progress, scale effects, and forward ordering on U.S. fiber demands. The potentials for substituting synthetic fibers are considerably smaller in the LDCs than in the DCs. The estimates show that the U.S. demand elasticity for cotton ranges from -0.02 to-0.87 in the short run, and from -0.65 to -5.5. in the long run. The estimates of other countries are less than unity, and the world demand elasticity of cotton is unity in Babula (1987). Arnade et al. (1993) estimates the import demand elasticities of some consuming countries for particular producing countries' cotton. They report that import demand elasticity varies substantially depending on the source of cotton. This suggest that price differentials are not sufficient to determine a country's import shares; consumers' tastes in importing country, political considerations, and long-term contracts are also important.

Sugar (Table 4.4)

The complexity of institutional restrictions in the sugar market has hindered attempts at econometric modelling. Government intervention in the market insulates domestic production from world price changes. The large fixed cost of sugar production also slows the supply response following market price changes. Supply response is slower in the LDCs than in the DCs, and the elasticities of both regions are low. Lord (1991) and Hwa (1985) have similar estimates of the world long-run supply elasticity of sugar, but this is much lower Adams and Behrman's (1976) estimate of .2.

The demand elasticities are very small, possibly reflecting the fact that sugar is used primarily as an input or as a complement to other products. The estimated world demand elasticity is -0.016 in Hwa (1985) and -0.04 in Lord (1991). The recent introduction of substitute sweeteners in DCs will increase the demand elasticity in the future. The income elasticities in DCs are very small, while those in LDCs, where income is lower and demand is still not saturated, are much larger.

Table 4.2 Elasticity estimates for coffee

	Comment	Demand			Supply		Cross-price
		short–run	long–run	income	short–run	long–run	
1	US	–0.07 ~ –0.77		0.81 ~ 3.1			
2	Box–Cox	–0.20	–0.34	–0.23			–0.14(sugar)
	log–log	–0.26	–0.39	–0.21			–0.15(sugar)
	linear	–0.16	–0.30	–0.23			–0.12(sugar)
3	Latin Ame.	–0.25		1.34			
	Brazil				0.28	0.29	
	ROW				0.08	0.10	
4	Brazil	–0.09		N.S.	0.03	0.36	
	Columbia	–0.14		0.41	0.16	0.74	
	Cote d'Ivoire				0.55	0.84	
	U.S.	–0.46		N.S.			
	France	–0.13		0.68			
	Germany	–0.17		0.98			
	Japan	–0.31		2.03			
5	US	–0.72		–0.19			–0.12(milk)
6	model1(52–85)	–0.37	–1.46	1.56 ~ 6.30			
	model2(52–73)	–0.15	–0.28	0.98 ~ –3.18			
7	World	–0.365	–0.479	0.447	0.133	0.872	
8	U.S.	–0.372		N.S.			
	EC	–0.067		0.597			
	Japan	–0.396		1.990			
	CPN	–0.168		1.073			
	World	–0.186		0.448			
	Brazil				0.093	1.1	
	Colombia				0.0673	0.96	
	Ivory Coast				0.55	0.73	
	Indonesia				0.285	1.05	
	ROW				0.0771	0.38	
	World				0.12	0.739	
9	Box–Cox						
	regular	–0.18		0.53			
	soluble	–0.05		–0.23			
	log–log						
	regular	–0.16		0.51			0.15(tea)
	soluble	–0.36		–0.10			–0.48(cola)
10	US	–0.216		0.006			
	ROW	–0.262		0.643			
	Brazil				0.2	0.44	
	Colombia				0.03	0.18	
	Latin Ame				0.03	0.14	
	Africa				0.12	0.44	
	Asia				0.1	0.43	
11	LDC	–0.55	–0.31	0.4		0.33	
	DC	–0.44	–0.24	0.2			
	CPN		–1.25	1.45			

1. Lange and Hsing (1994)
   - Estimate three functional forms (Box-Cox, log, linear regression).
   - Use time series data (1968-1990).
   - Static, single equation model.

2. Okunade (1992)
   - Single equation demand model.
   - Incorporate the dynamic forces of habit formation as a regressor in a flexible Box-Cox demand model.

3. Lord (1991)
   - Estimates traditional demand and supply equations with lag structures.
   - Single equation model.
   - 1960-1987.

4. Akiyama and Varangis (1990)
   - Dynamic global coffee market model.
   - Simultaneous equilibrium model with supply block (new plantings, production, consumption, and exports for 31 regions) and demand block (demand in 22 ICA importing member countries).

5. Heien and Pompelli (1989)
   - Estimate AIDS model.
   - Use Household Food Consumption Survey (HFCS) data by USDA (1977-1978).
   - Incorporate demographic variables in the demand system.
   - Static model.

6. Bates and Conteras (1988)
   - Estimate dynamic error correction model.
   - Annual consumption of coffee in U.S. (1950-1985).

7. Hwa (1985)
   - Dynamic simulation model, formulated in a disequilibrium framework.
   - Emphasize the role of price adjustment.
   - Use OLS and IV methods by using data from 1955 to 1977.

8. Akiyama (1982)
   - Reported estimate obtained from Pieterse and Silvis (1988).

9. Huang et al. (1980)
   - Typical static demand model.
   - Single equation (1963-1977).

10. Singh and De Vries (1977)
    - Reported estimate obtained from Pieterse and Silvis (1988).

11. Adams and Behrman (1976)
    - Estimate traditional demand and supply equations with some lags.
    - 1956-1971

Table 4.3 Elasticity estimates for cotton

	Comment	Demand			Supply		Cross-price
		short-run	long-run	income	short-run	long-run	
1	Latin Ame.	-0.26		0.35	0.13	0.38	
2	US				0.36	0.64	
3		-0.24	-3.43	N.S.	0.38	2.37	N.S.
4	US	-0.2	-0.44	1		1.35	
	LDC		-0.18	0.5	0.07	0.77	
5	EC10	2.7475					
	Japan	0.9780					
	Korea	0.1201					
	ROW	0.8110					
	World	1.0282					
6	US		-4.6				
7	US	-0.24					
8	US	-0.02					
9	US	0.87					
10	US		-5.5				
11	Natural fiber	-0.617					
	Manmade fiber	-0.431					
12	Japan						
	Nicaragua		-15.5				
	U.S.		-0.1				
	Egypt		-1.19				
	USSR		-2.24				
	France						
	Turkey		-8.33				
	U.S.		-16.45				
	Egypt		-0.73				
	USSR		-6.02				
	Hong Kong						
	U.S.		-8.01				
	Pakistan		-14.72				
	USSR		-20.7				

*5-10: estimates of export demand for US cotton.
*6-10: excerpted from Gardiner and Dixit (1986)
* 11: estimates of demand for US fibers
* 12: estimates of import demand in consuming countries for producing countries' cotton (e.g. Japan's import demand elasticities for Nicaragua's cotton).

1. Lord (1991)
  - Estimates traditional demand and supply equation with lag structures.
  - Single equation
  - 1960-1987

2. Duffy et al. (1987)
  - Cotton acreage response was estimated for 4 distinct production regions in U.S.
  - Partial adjustment model.
  - U.S. cotton supply elasticity is a weighted elasticity of 4 region's supply elasticities.

3. Monke and Taylor (1985)
  - Estimate a model with quantitative controls on international trade.
  - Cross-section time-series data set.
  - Note that Duffy et al. (1987) estimate is U.S. cotton supply elasticity; while this estimate is other cotton exporters' supply elasticity.

4. Adams and Behrman (1976)
  - Estimate traditional demand and supply equations with some lags.
  - Single equation static model.
  - 1956-1971.

5. Babula (1987)
  - Multiregional Armington model of U.S. cotton exports
  - Estimates using SUR.
  - Static model.

6. Liu and Roningen (1985)
  - 1984 base year, calculation technique.
  - The calculation technique is one way to estimate the price elasticity of export demand, which depends on consumption, inventory, and supply (elasticities) in importing and exporting countries. This technique allows us to evaluate the influence of the components that make up the elasticity of export demand.

7. Green and Price (1984)
  - 1986 base year, simulation technique.
  - Simulation technique uses the dynamic price export elasticity formula which depends on export demand at t and t+1, price level at t and t+1. By changing the price and simulating the model over time, the dynamic elasticity can be calculated from the formula.

8. Taylor and Collins (1981)
  - 1961-1980, estimate by SUR

9. Collins (1979)
  - 1958-1977, estimate by OLS

10. Johnson (1977)
  - 1970 base year, calculation technique.

11. Shui et al. (1993)
  - Estimates simultaneous equilibrium model by using iterative 3SLS.
  - 1950-1987.

12. Arnade et al. (1993)
  - Dynamic error correction model.
  - Single equation model.

Table 4.4. Elasticity estimates for sugar

	Comment	Demand			Supply		Cross-price
		short-run	long-run	income	short-run	long-run	
1	Latin Ame. US EC ROW	-0.04 -0.07 N.A. -0.04		0.66 0.70 0.92 0.62	0.04 0.09 0.11 0.03	0.05 0.18 0.12 0.03	
2	US EC Japan	-0.2 -0.12 -0.05				0.28 0.50 0.50	0.05(corn) 0.01(corn)
3	World	-0.016		0.373	0.006	0.019	
4	DC LDC CPN	-0.02 -0.05 -0.12	-0.04 -0.05 -0.48	0.30 0.78 0.36	0.04 0.10 0.24	0.15 0.19 0.71	

1. Lord (1991)
   - Estimate traditional demand and supply equation with lag structures.
   - Single equation (1960-1987)

2. Tyers and Anderson (1988)
   - Estimate GLS model which is multi-commodity, multi-country dynamic simulation model.
   - 1980-1982 base period.

3. Hwa (1985)
   - Dynamic simulation model, formulated in a disequilibrium framework.
   - Emphasize the role of price adjustment.
   - Use OLS and IV methods by using data from 1955 to 1977.

4. Adams and Behrman (1976)
   - Estimate traditional demand and supply equations with some lags.
   - Single equation static model.
   - 1956-1971.

4.4 The Trade Effects of Input and Commodity Taxes

There are two things standing in our way of building reliable trade models for coffee, sugar and cotton. First, it is difficult to capture the complexity of those markets using a simple model. Second, even if we make the heroic assumptions necessary to build such a model, we cannot be confident about what parameter values to use. However, despite their manifest imperfections, we think that formal empirical models can provide useful estimates of the effect of policy changes.

This section illustrates the use of a multicommodity trade model to estimate the effect of internalization policies. We consider two types of policies. The first is a tax on fertilizer. Our survey of environmental costs in Chapter 3 indicated that fertilizers are a leading cause of environmental damage in agriculture. Taxing their use is one way to force producers to internalize costs. The second policy instrument is a producer output tax. If producers are competitive (as we assume) a tax of x% on output is equivalent to an equal increase in marginal cost. Therefore we can think of the output tax as describing the effect of a collection of (unspecified) policies which increase marginal costs. We use the model to illustrate how these policies effect prices and trade, when they are applied either unilaterally or multilaterally.

Model Description

Our illustration uses the SWOPSIM model, developed at the Economic Research Service (ERS) of USDA. This is a simplified world trade model used to estimate the effects of policy changes. The SWOPSIM model is characterized by three basic features: (i) it is a nonspatial price equilibrium model, (ii) it is an intermediate-run static model that represents world agricultural markets for a given year, and (iii) it is a multi-product, multi-region partial equilibrium model. To use this model to describe world agricultural trade, we make the following assumptions:

(1) World agricultural markets are competitive, in that countries operate as if they have no market power.

(2) Domestic and traded goods are perfect substitutes in consumption, and importers do not distinguish commodities by source of origin.

(3) A geographic region, though possibly containing many countries, is one market place.

The model consists of supply and demand equations with constant elasticities and summary policy measures. For each region i and each product j in the model, demand (D) and supply (S) relationships are

$$D_{ij} = D_{ij}\ (CP_{ij},\ CP_{ik},\ QS_{ih},\ TD_{ij})$$
$$S_{ij} = S_{ij}\ (PP_{ij},\ PP_{ik} \text{ or } CP_{ik},\ TS_{ij})$$

where CP_{ij} and PP_{ij} are domestic "incentive" prices facing consumers and producers, respectively, of product j in country i. CP_{ik} and PP_{ik} are consumer and producer prices of products related to product j in either consumption or production, respectively. QS_{ih} in the demand function accounts for the derived demand for the product as an intermediate input into the production of product QS_{ih}. TD_{ij} and TS_{ij} in the demand and supply functions account for policies or economic factors that might shift the functions over time.

Trade is the difference between total domestic supply and total domestic demand. World markets clear when net trade of a product across all regions sums to zero:

$$\Sigma_i\ T_{ij} = \Sigma_i\ S_{ij} - \Sigma_i\ D_{ij} = 0.$$

The policy structure is embedded in equations linking domestic and world prices. Domestic incentive prices depend on the levels of consumer and producer support, modeled in terms of consumer and producer support price wedges CSW_{ij} and PSW_{ij}, and on world prices denominated in local currency:

$$CP_{ij} = CSW_{ij} + F(E_i{*}WP_j)$$
$$PP_{ij} = PSW_{ij} + G(E_i{*}WP_j)$$

where E_i is the exchange rate of country i with respect to the U.S. dollar, and WP_j is the world price of product j measured in the U.S. dollars. The functions F(.) and G(.) allow changes in world and domestic prices to differ; the elasticity of these functions is referred to as a price transmission elasticity. If this is less than 1, domestic producers or consumers are cushioned from world price instability; if the elasticity equals 1, then 100% of a world price change is passed on to the domestic market.

The basic SWOPSIM model of ERS, described in Roningen et al. (1991), covers 22 commodities and 36 countries. The version of SWOPSIM used in this study covers 4 commodities and 6 regions. The regions modeled are US (United States), EU (Europe), LA (Latin America), AS (Asia), AF (Africa), and RW (rest of the world), and commodities include cotton, sugar, coffee, and fertilizer. The model is designed to represent the 1989 (base marketing year) world agricultural markets.

This model includes supply and demand equations for the three commodities, and derived demand equation for fertilizer. The cross-price elasticities of the three commodities are assumed to be zero. That is, the three commodities are not linked in any way except through fertilizer price in this model. This study assumes that these costs are correlated with fertilizer use.

The SWOPSIM model does not explicitly include a fertilizer sector. However, we can follow Haley's (1993) method of incorporating that sector. His method uses the fact that fertilizers are an input, as are feedgrains in the SWOPSIM framework, and they can be treated in an analogous manner. The quantity of commodities using fertilizer enter into the fertilizer demand equation; the quantities are exponentially weighted by their proportion of total fertilizer use. The specific demand and supply equations used in this model are as follows (subscript i is suppressed for the subsequent equations).

$$D_f = A * [CP_f^{\varepsilon} * CP_t^{\varepsilon t} * CP_s^{\varepsilon s} * CP_c^{\varepsilon c}] * [S_t^{\alpha t} * S_s^{\alpha s} * S_c^{\alpha c}]$$
$$S_f = B * [PP_f^{\eta} * PP_t^{\eta t} * PP_s^{\eta s} * PP_c^{\eta c}]$$

where A and B are constants or shift factors, and fertilizer, cotton, sugar and coffee are denoted as f, t, s, c, respectively; α_i is shares of fertilizer use for each commodity, and ε and η are own-price demand and supply elasticities of fertilizer respectively. ε_i and η_i denote cross-price demand and supply elasticities.

Data

The data on trade quantities and the elasticity estimates we used are given in tables at the end of this section. We need data for each commodity in each region. We obtain: global supply, demand and trade data for each commodity from FAO (1992a, 1992b, 1992c); world prices from the IMF (1992); and price transmission elasticities from Sullivan (1990). Other macroeconomic data such as supply growth rate, income, and population are obtained from Sullivan et al. (1992). The SWOPSIM model of ERS includes some data on policy wedges, but this is not sufficient for our study. We assume that in the base year there are no policy wedges (consumers and producers face world price).

Supply and demand price elasticities for the three commodities are based on our review of estimates described in the previous section. The elasticities of fertilizer demand are based on Ray (1982), Boyle (1981), Bonnieux and Rainelli (1987), and Burrell (1989). Own-price elasticities obtained by Ray range from -0.32 to -0.49 for different years in U.S., and Boyle obtains similar values for Ireland (-0.54 to -0.62 for different periods). Bonnieux and Rainelli's values for France are -0.33 in the short-run and -1.10 in the long-run. Burrell's estimates ranges between -0.47 and -0.5 for Marshallian elasticities and between -0.22 and -0.24 for Hicksian elasticities for U.K..

A closer examination of the fertilizer demand equation is needed to determine how these estimates should be used. The fertilizer demand equation can be writeen as

$$D_f^* = D_f\,[P_f,\ P_j,\ S_j(P_j)]$$

where j denotes all commodities except fertilizer. The change in fertilizer demand due to a change in fertilizer price P_f is given as

$$\partial D_f^*/\partial P_f = \partial D_f/\partial P_f + \Sigma_j[\partial D_f/\partial S_j)(\partial S_j/\partial P_f) .$$

The first term on the right hand side is the substitution effect and shows the change in fertilizer use through technical substitution, holding constant production of other commodities. The second term is the expansion effect and shows the additional change in fertilizer demand due to adjustments in output level caused by the change in fertilizer demand. Since this second term is non-positive, it reinforces the negative substitution effect. The elasticity can be expressed as

$$\varepsilon_f^M = \varepsilon_f^H + \Sigma_j\, \varepsilon_{sj}\, \varepsilon_{cj}$$

where ε_f^M is the Marshallian demand elasticity of fertilizer and ε_f^H is the Hicksian elasticity. ε_{sj} is the percentage change in fertilizer demand due to the percentage change in output j, and ε_{cj} is cross-price elasticity of fertilizer with respect to product j. The Marshallian elasticity measures the potential impact of change in fertilizer prices on fertilizer use. Boyle's and Ray's elasticities are Hicksian, while Bonnieux and Rainelli's estimate is Marshallian. Burrell reported both elasticities. When estimating Marshallian elasticity, it is necessary to include commodities that use fertilizer for the second term of the above equation. The choice of which commodity to include depends on the model for analysis.

We were unable to obtain complete data on fertilizer elasticities for each region needed for the above equation, and therefore assume fertilizer demand elasticity to be -0.5 for every region. Ssensitivity analysis shows that this assumption does not affect the results significantly. Fertilizer cross-price elasticity (ε_c) for each of the crops that use fertilizer is calculated as follows.

$$\varepsilon_c = FS * TFE * \eta / CPV$$

where FS is fertilizer share, TFE is total fertilizer expenditure, and CPV is crop production value. The fertilizer share data come from Haley (1993) and Lele et al. (1989) for Europe and Africa, respectively. In other regions, it is assumed that the share data are the average of Europe and Africa. We were unable to find estimates of fertilizer supply elasticities. We set the elasticity equal to 1. We regard this as a high value, so our results probably exaggerate the effects of taxes.

Nitrogen is the principal cause of environmental damage from fertilizer, although nitrates also contribute to water pollution, health hazard, and eutrophication. The share of nitrogen fertilizer in total fertilizer use is about 50%, with increasing trend. We therefore focus on nitrogen fertilizer use; most of our fertilizer data (with the exception of elasticities) refers to nitrogen.

Simulation Results

Among the policy instruments for limiting fertilizer use, a tax on fertilizer is administratively the easiest option. We consider two types of policy changes; fertilizer tax and output tax. The output tax affects fertilizer demand indirectly, but, as we mentioned above, this tax can also be viewed as a summary statistic of other internalization policies which affect marginal cost. Given the low elasticity of fertilizer demand, a significant impact of fertilizer demand would require a very high level of taxation. In this study, 50% fertilizer tax and 20% output tax are considered.[10] In each case, we compare the effects of a

[10] These taxes are much higher than the level that was suggested was plausible in Chapter 2. We use such large taxes to show that even substantial levels of intervention lead to modest changes in trade.

unilateral and multilateral tax. The unilateral taxes are imposed on the region whose production level is the largest in the world. The following four cases are simulated.

Case I : unilateral fertilizer tax (fertilizer tax on AS)
Case II : multilateral fertilizer tax (fertilizer tax on every producing regions)
Case III : unilateral output tax (cotton tax on AS, coffee tax on LA, and sugar tax on AS)
Case IV : multilateral output tax (output tax on every producing regions)

The simulation results are reported in Tables 4.4 (price effects), 4.5 (production effects), and 4.6 (trade effects). We ran each simulation twice, first using the elasticity estimates reported at the end of the section, and then doubling the supply elasticities. We interpret the results with the higher supply elasticities as being longer-run outcomes. These outcomes are given in parentheses in Tables 4.4-4.6.

The 50% fertilizer tax (imposed on consumers) causes a reduction in fertilizer production in every region. The fertilizer tax in one region reduces demand for fertilizer there, which in turn reduces the world demand for fertilizer. Thus, world fertilizer production and world fertilizer price decrease. The absolute reduction is larger in DCs than in LDCs due to the high price transmission elasticities in DCs. The change of fertilizer production in the tax-imposing region is similar to other regions, since the tax mainly affects consumption; the effect on producer price is similar in every region. The reduction in output more than doubles when the tax is imposed multilaterally.

The unilateral tax slightly increases the production of the three commodities in every region except in the tax-imposing region. This is the "market share" effect, which we see is small. The higher consumer price in the tax-imposing region drives up costs of production, reducing production of the three commodities there. Production of these commodities in other regions increases. The amount of increase is less than 2% both in the short-run and in the long-run. The long-run and short-run effects are almost same for world fertilizer production.

The reduction in production due to price change has trade effects on each region. For the final commodities, this change is insignificant both in the unilateral and multilateral cases. For fertilizer, the trade effect is substantial. The unilateral fertilizer tax in Asia improves its trade balance of fertilizer, since the decrease of demand exceeds the decrease of production. Using a multilateral rather than a unilateral tax has an ambiguous effect on the size of the trade effect.

The imposition of the 20% output tax reduces the production of the commodity in the tax-imposing regions, and increases production in the non-taxing regions. The world price to consumers increases substantially, as world total production declines. The total reduction of world production doubles when all countries impose the tax. Each (original) tax-imposing region has a smaller reduction of production when other countries use the tax (the multilateral case).

The (unilateral) tax-imposing region suffers a loss in competitiveness in world markets, which is reflected in the deterioration of its trade balance. Since the multilateral tax reduces production almost equally in each region, it does not create substantial changes in trade balance. However, DCs have a larger price transmission elasticity, so they face more of the adjustment in trade.

The commodity taxes cause the production of fertilizer in DCs to decrease, while in LDCs production increases. This occurs because of the difference in price transmission elasticities in the two regions. The commodity taxes cause the derived demand for fertilizer to shift in, leading to a movement down the world supply curve, and a reduction in world price of fertilizer. However, this decline in price is not transmitted equally to all regions. Regions with a high price transmission elasticity face a relatively large reduction in producer price of fertilizer, which leads to a relatively large decrease in their supply. Other regions, with a low price transmission elasticity, can actually increase their supply as world demand shifts toward those regions. Thus, the effect on world fertilizer supply (and consumption) is ambiguous in general. In our simulations, the commodity taxes actually lead to a small increase in world fertilizer production (and consumption).

Table 4.4 Percentage Changes in World Price

	CASE I	CASE II	CASE III	CASE IV
Cotton	1.788 (1.208)	3.230 (2.214)	11.225 (13.608)	20.254 (25.266)
Sugar	0.380 (0.282)	0.975 (0.709)	7.081 (9.035)	18.574 (24.258)
Coffee	0.181 (0.213)	1.732 (1.260)	12.090 (16.520)	20.919 (28.521)
Fertilizer	−7.240 (−4.130)	−17.577 (−10.274)	−1.116 (−0.011)	−2.496 (−0.557)

Table 4.5. Percentage Changes in Production

	CASE I	CASE II	CASE III	CASE IV
Cotton				
US	1.433 (1.719)	0.885 (1.434)	8.064 (20.163)	0.259 (7.676)
EU	1.182 (1.378)	0.437 (0.813)	1.524 (3.535)	0.127 (1.422)
LA	0.411 (0.445)	−0.930 (−0.868)	1.601 (3.793)	−3.181 (−4.966)
AS	−1.441 (−1.337)	−0.895 (−0.737)	−7.585 (−13.610)	−5.249 (−8.140)
AF	0.442 (0.532)	−0.211 (−0.041)	2.131 (5.089)	−4.234 (−6.569)
WORLD	−0.329 (−0.223)	−0.588 (−0.405)	−1.915 (−2.301)	−3.384 (−4.105)
Sugar				
US	0.306 (0.350)	0.024 (0.154)	3.492 (9.035)	0.259 (4.405)
EU	0.122 (0.129)	−0.065 (−0.035)	1.189 (2.984)	−0.185 (1.481)
LA	0.086 (0.101)	−0.136 (−0.093)	1.039 (2.629)	−3.410 (−5.117)
AS	−0.544 (−0.520)	−0.345 (−0.293)	−7.723 (−14.008)	−5.071 (−7.577)
AF	0.051 (0.050)	−0.223 (−0.220)	0.421 (1.043)	−1.366 (−2.077)
WORLD	−0.067 (−0.050)	−0.171 (−0.124)	−1.204 (−1.528)	−2.986 (−3.802)
Coffee				
US	–	–	–	–
EU	–	–	–	–
LA	0.092 (0.093)	−0.323 (−0.260)	−3.814 (−6.454)	−2.384 (−2.988)
AS	−0.592 (−0.583)	−0.306 (−0.235)	2.076 (5.165)	−2.526 (−3.194)
AF	0.067 (0.080)	−0.024 (0.070)	2.059 (5.166)	−2.555 (−3.199)
WORLD	−0.038 (−0.027)	−0.259 (−0.190)	−1.471 (−1.840)	−2.404 (−2.960)
Fertilizer				
US	−7.240 (−8.239)	−17.933 (−19.733)	−2.932 (−1.756)	−2.386 (−1.146)
EU	−7.049 (−8.109)	−17.628 (−19.527)	−1.744 (−0.541)	−2.333 (−0.681)
LA	−3.891 (−4.354)	−9.961 (−10.791)	0.682 (2.608)	11.241 (8.214)
AS	−3.753 (−4.252)	−9.526 (−10.488)	4.381 (4.670)	2.624 (2.726)
AF	−3.937 (−4.479)	−9.965 (−10.961)	−4.441 (−11.441)	6.783 (14.724)
WORLD	−4.956 (−5.652)	−12.475 (−13.690)	0.582 (1.170)	0.549 (1.378)

Percentage Changes in Net Exports

	CASE I	CASE II	CASE III	CASE IV
Cotton				
US	2.691 (3.119)	1.907 (2.740)	13.535 (32.223)	2.611 (14.422)
EU	1.094 (0.849)	1.646 (1.230)	6.218 (8.747)	8.958 (11.820)
LA	1.856 (1.858)	–2.693 (–2.675)	8.109 (16.745)	–7.601 (–13.055)
AS	–4.903 (–5.001)	–0.934 (–1.203)	–24.284 (–49.553)	–5.848 (–14.876)
AF	1.184 (1.256)	0.158 (0.312)	6.135 (12.518)	–5.015 (–8.736)
Sugar				
US	1.877 (1.978)	1.189 (1.518)	24.212 (52.551)	15.958 (44.976)
EU	3.222 (2.869)	3.576 (2.751)	45.184 (75.415)	73.125 (114.018)
LA	0.308 (0.338)	–0.249 (–0.164)	4.061 (8.973)	–7.329 (–11.567)
AS	–2.465 (–2.436)	–0.838 (–0.827)	–33.536 (–64.549)	–9.621 (–18.088)
AF	1.207 (1.050)	–1.389 (–1.737)	15.239 (25.764)	7.668 (5.669)
Coffee				
US	0.073 (0.063)	0.509 (0.372)	3.369 (4.511)	5.583 (7.360)
EU	0.039 (0.034)	0.275 (0.022)	1.832 (2.458)	3.052 (4.037)
LA	0.133 (0.133)	–0.424 (–0.343)	–5.425 (–9.437)	–3.595 (–4.849)
AS	–2.685 (–2.655)	–0.679 (–0.551)	13.272 (28.942)	–6.159 (–7.811)
AF	0.114 (0.134)	0.067 (0.182)	3.310 (8.016)	–3.532 (–4.544)
Fertiliz				
US	–231.740 (–226.920)	–147.960 (–145.308)	–132.794 (–209.040)	–121.072 (–204.372)
EU	–113.565 (–113.203)	–88.320 (–90.145)	–40.597 (–54.388)	–50.844 (–61.424)
LA	–28.965 (–27.629)	30.651 (32.385)	12.868 (10.746)	44.633 (42.112)
AS	86.804 (86.163)	38.171 (39.168)	34.211 (47.701)	22.223 (33.072)
AF	–234.047 (–232.351)	126.955 (124.745)	–257.808 (–323.347)	437.372 (397.502)

4.5 Conclusion

This chapter illustrated one approach to modeling the international effects of internalizing environmental externalities. Internalization policies change prices within the country that imposes the policies; this changes supply and/or demand, and therefore changes imports. If the policies are imposed in a region that accounts for very little production, consumption, or trade, they have no international effects via the market.[11] We were interested, in the situation where the policies are applied over a sufficiently broad region that there are trade effects. Taking the policies as given, we then want to determine their effects on consumption, production, and trade throughout the world. This information is important because countries are concerned that their environmental policies might damage their competitive position. The information is also important because consumption and/or production of some goods causes environmental damage; shifting production or consumption shifts environmental damage.

We began with a description of the markets for coffee, sugar and cotton, followed by a review of the empirical literature. The markets have been influenced by changes in taste and technology, and by a wide variety of government intervention. Standard trade models, which emphasize the role of prices, neglect many important aspects of the markets. The literature review shows that there is considerable disagreement about the probable magnitude of parameters. These observations concerning the markets and the empirical literature make us cautious about the prospects of obtaining reliable estimates of the international effects of internalization policies. However, we think that a formal model gives us a better idea of likely outcomes than does casual reasoning.

With these modest expectations, we adapted an existing trade model to study the international effects of fertilizer and commodity taxes. The model has a number of advantages and limitations. The advantages include its simplicity, availability, and "breadth". The simplicity makes it (relatively) easy to adapt the model for different policy experiments, and to obtain results quickly. The model is available from ERS, and is well-documented. It therefore provides a practical tool for the sort of policy analysis we are interested in. The model is "broad", in the sense that it can include a large number of sectors and regions. Therefore it can be used for a large variety of policy questions.

There are also significant limitations to the model. First, it really is "only" a trade

[11] There may of course be international effects if the pollution problems are transboundary.

model, and as such does not directly describe the environment. We know that the quantities in the model are related to environmental variables, but this relation is outside the model. We can, for example, learn something about fertilizer use, but this model does not relate that variable to environmental quality. We should not exaggerate this limitation: there is an advantage to the division of labor in modeling, as in other activities. Second, the model is static; we can obtain snapshots of policy effects over different time periods only by changing elasticities. Also, in this model, outcomes of policy experiments do not depend on initial conditions. We know this is not true in the world. (The model could be altered to include this kind of dependency, but that has not yet been done.)

Our simulations illustrate the kinds of results that a static, partial equilibrium, multi-commodity model is likely to generate. In many, but not all cases, even quite large taxes have modest effects on prices and trade flows. Actual environmental taxes would probably be much smaller than the values we used.

Despite its obvious limitations, we think this sort of analysis can be useful for policy discussion, provided that we view the results as being no more than suggestive. Continued empirical work of the sort we reviewed, and sustained effort in developing models of the sort we used, should be encouraged. We can expect incremental advances from these efforts. The results should be routinely applied to the analysis of the international effects of internalization policies. This chapter has illustrated the practicality of that application. However, we think that it is also worth developing a completely different type of trade model, in which the environment is central, and which allows us to study dynamics. This is the subject of the next chapter.

Summary of elasticities in each region

US

SUPPLY	CT	SU	CF	FE	DEMAND	CT	SU	CF	FE
CT	.64	.00	−.05	−.02	CT	−.20	.00	.00	.00
SU	.00	.50	.00	.00	SU	.00	−.24	.00	.00
CF	.00	.00	.50	−.01	CF	.00	.00	−.37	.00
FE	−.13	−.02	.00	1.00	FE	.00	.00	.00	−.50

EU

SUPPLY	CT	SU	CF	FE	DEMAND	CT	SU	CF	FE
CT	.50	.00	.00	.00	CT	−.52	.00	.00	.00
SU	.00	.17	.00	−.01	SU	.00	−.50	.00	.00
CF	.00	.00	.30	−.02	CF	.00	.00	−.20	.00
FE	−.01	−.03	.00	1.00	FE	.00	.00	.00	−.50

LA

SUPPLY	CT	SU	CF	FE	DEMAND	CT	SU	CF	FE
CT	.30	.00	.00	−.05	CT	−.52	.00	.00	.00
SU	.00	.30	.00	−.01	SU	.00	−.50	.00	.00
CF	.00	.00	.28	−.02	CF	.00	.00	−.20	.00
FE	−.29	−.17	−.33	1.00	FE	.00	.00	.00	−.50

AS

SUPPLY	CT	SU	CF	FE	DEMAND	CT	SU	CF	FE
CT	.50	.00	.00	−.06	CT	−.45	.00	.00	.00
SU	.00	.45	.00	−.02	SU	.00	−.40	.00	.00
CF	.00	.00	.30	−.02	CF	.00	.00	−.30	.00
FE	−.20	−.04	−.01	1.00	FE	.00	.00	.00	−.50

AF

SUPPLY	CT	SU	CF	FE	DEMAND	CT	SU	CF	FE
CT	.40	.00	.00	−.03	CT	−.47	.00	.00	.00
SU	.00	.12	.00	−.01	SU	.00	−.27	.00	.00
CF	.00	.00	.30	−.01	CF	.00	.00	−.30	.00
FE	−.53	−.18	−.20	1.00	FE	.00	.00	.00	−.50

Summary of trade data used in SWOPSIM (1989, thousand metric ton)

US

	IMPORT	EXPORT	NET TRADE	SUPPLY	DEMAND
CT	1	1533	1532	2655	1123
SU	1713	450	-1263	6004	7267
CF	1181	47	-1134	1	1135
FE	3542	2961	-581	12576	13157

EU

	IMPORT	EXPORT	NET TRADE	SUPPLY	DEMAND
CT	2012	257	-1755	327	2082
SU	6634	8418	1784	21941	20157
CF	2594	304	-2290	1	2291
FE	5961	7537	1576	17928	16352

LA

	IMPORT	EXPORT	NET TRADE	SUPPLY	DEMAND
CT	273	698	425	1537	1112
SU	1306	10517	9211	26806	17595
CF	43	2667	2624	3664	1040
FE	1358	692	-666	3334	4000

AS

	IMPORT	EXPORT	NET TRADE	SUPPLY	DEMAND
CT	3236	1466	-1770	8232	10002
SU	10170	4632	-5538	28909	34447
CF	433	667	234	1108	874
FE	8303	3383	-4920	31392	36312

AF

	IMPORT	EXPORT	NET TRADE	SUPPLY	DEMAND
CT	188	878	690	1351	661
SU	3219	2588	-631	7911	8542
CF	171	1011	840	1269	429
FE	525	546	21	941	920

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5. A Dynamic North-South Model of Trade and the Environment

5.1 Introduction

The Brundtland report (WCED 1987) stressed that much environmental damage in Third World countries (the "South") arises from the production of agricultural and mining commodities exported to OECD countries (the "North"). Changes in the environment may affect individuals directly (e.g., a flood caused by erosion) or indirectly through the market (e.g. by changing prices). The distribution of direct environmental costs arising from production depends on whether externalities are local or transnational. For example, international trade in tropical timber has caused extensive ecological damage to tropical rain forests in Southeast Asia and the Amazon. The resulting loss of biodiversity and the possibility of global change in climate impose costs on people throughout the world. Other direct environmental costs, such as soil erosion, depletion of water resources, landslides and floods, are borne almost entirely by local populations in the producing areas.

There are also indirect environmental effects, which appear only insofar as they lead to changes in prices and trade flows. The distribution of these effects, over time and across different geographical groups, may be very different than that of the direct costs. For a commodity that involves trade, these market-driven costs are always transnational. For example, unsustainable harvest of hardwoods, and the associated low production costs, allow consumers in the North to enjoy low prices in the short run, possibly at the expense of high prices later. Producer profits also change over time, as current decisions change the environmental stock, and future production costs.

We propose a model which allows us to analyze the relation between production practices and environmental change, and to determine how this relation alters the benefits of trade. Here we ignore the direct costs of environmental damage, of the type described above. This allows us to focus exclusively on the narrower issue of environmental costs which affect people only by means of the market. The direct, and the indirect (market-mediated) costs are distinct, as is their distribution. Our choice of focus is motivated by this recognition, not by the belief that one type of costs is more important than the other. The magnitude of the market-mediated costs may bear no relation to whether an effect such as global warming occurs.

The four essential features of our model are: (i) Production of a commodity in the South requires an environmental input (hereafter, "the environment"). (ii) The stock of the environment, and thus the costs of production, change over time, in a manner which depends on the current stock and current production practices (e.g. fertilizer application, investment in drainage systems). (iii) Producers do not completely internalize the costs of their current decisions. (iv) Although produced in the South, the commodity is primarily consumed in the North. There are two secondary features of the model: (v) The South consists of two regions, possibly with different policies and physical characteristics (technology and the environment). (vi) Processors in the North may exert monopsony power. The simple model mentioned in Chapter 2.4 (Figure 2.3) captures the four principal features listed above. This chapter shows how to construct a model which can be used to simulate policy changes, and which serves as a basis for estimation. The first two features of the model mean that current production decisions determine future marginal production costs, and therefore determine the future supply function. The third feature reflects the idea that there are market failures, such as imperfect property rights or production externalities. The effect of these market failures is felt primarily in the future, as is the case with environmental damage. The fourth feature means that international trade distributes the costs and benefits of the market failure. Modeling the South as two regions allows us to analyze the effect of differences in technology, natural conditions, and policy. We include the possibility that processors exert monopsony power because many writers claim that this is an important feature of some commodity markets.

We can use this model to address a variety of questions. The central question concerns the welfare effects, for producers in the South, processors, and consumers in the North, of various internalization policies. When does a policy benefit consumers but harm producers? Our model includes standard tax/subsidy policies in addition to policies which involve institutional change. In the South, inputs may be taxed or subsidized, and institutional reform may strengthen property rights. The North can impose a tariff on the commodity (an input) or a consumption tax on the good. Even if there is no substitution in production, these two policies are not equivalent when processors exercise monopsony power. Since the model is dynamic, we can determine how the welfare effects change over time. The evolution of the environment may also be of interest for reasons which are not included in the model, as occurs when there are direct costs of environmental degradation. By considering policy differences, we are able to study the consequences of both unilateral and multilateral internalization effort. We can then explain why the view of unilateral internalization which is based on static models is likely to be misleading.

Section 5.2 presents the model formally and describes its qualitative properties. In Section 5.3 we choose specific parameter values and present simulations which indicate how the model can be used for policy analysis. We address the problem of estimating the model in Section 5.4, and provide concluding comments in Section 5.5.

5.2 The Basic Model

This is a partial equilibrium model, with two exporting countries in the South and one importing country, the North. Production in the South requires purchased inputs (e.g. pesticides), labor, and a factor which we refer to as "the environment". This factor may be something very specific, such as nitrogen carry-over, or it may be an index of water and soil quality. Purchased inputs such as pesticides damage the environment, and another costly activity, which we call effort (e.g., investment in terracing), protects it. Producers take prices as given and choose inputs and effort (in environmental conservation) to maximize the sum of profit and the value they impute to the environmental stock. We discuss the second component of producers' maximand below. Producers' decisions and the current level of the environmental stock determine the current supply of the commodity and the change in the environmental stock. The commodity is imported by oligopsonistic processors who convert it to a finished good, which is sold to consumers in the North. Processors take prices as given in the output market. In order to get closed form solutions, we assume that production in the South and processing in the North are described by Cobb-Douglas production functions, consumers have constant elasticity of demand, and the growth equation for the environmental stock is logistic.

The "representative producer" in country i in the South has profits π_i (inclusive of return to labor) given by:

$$\Pi_{it} = p_t Z_{it}^{\beta_1} C_{it}^{\beta_2} L_i^{\beta_3} - w(1+\tau_i)C_{it} - (1-s_i)E_{it} . \tag{1}$$

(For a definition of notation see Table 5.1.) The price of output at time t is p_t; the stock of the environment in country i at time t is Z_{it}; C_{it} is the level of the purchased input (e.g. chemicals, pesticide); L_i is the labor input, which we hereafter take as fixed, and normalize to 1; w is the (constant) price of the purchased input; τ_i is the tax on the purchased input; E_{it} is the conservation effort, measured in units of money; and s_i is the subsidy on effort. Conservation effort in the current period has no effect on current output.

Table 5.1. Variable Descriptions and Simulation Values

	Vars	Description	Value
Exogenous	Z_0	Initial level of environment in the two countries	8
	K_0	steady state environment with no human intervention	8
Endogenous	p	price producers receive in the South	
	$\bar{Q}$	price processors receive for the final product	
	$\bar{p}$	price for the raw material that the processors pay	
	Q	price of the final product to the consumers	
	C_t	purchased input	
	E_t	effort level	
	Z_t	environment	
	y_t	supply	
	q_t	production	
Fixed Inputs	L_i	labor	1
	F	fixed factor	1
	w	price of purchased inputs	.01
Policy Variables	τ_i	tax on purchased inputs	0 or .2
	s_i	subsidy on effort	0 or .2
	τ_p	tariff	0 or .2
	τ_c	sales tax	0 or .2
	λ_i	institutional parameter	0 or.01 or .02
Parameters	β_1,β_2,β_3	input shares in the supply function	.6, .2, 0
	α	constant of decay/growth for the environment	.055
	ϕ	scale for effort	.5
	γ	input shares on the production function	.4
	M_c	mark-up	.1
	η	elasticity of demand	4
	ρ	discount rate	.0001
	A, K	constants	1, 15
	Choke Price	limit used to calculate consumer surplus	1

The change in the environmental stock in country i is given by

$$Z_{i,t+1} - Z_{i,t} = \alpha Z_{i,t}(K_0 - C_{it} + E_{it}^{\phi} - Z_{i,t}) . \tag{2}$$

The steady state stock level in the absence of human intervention is K_o. The steady state as a function C and E is $K_o - C + E^{\phi}$. Thus, chemical inputs degrade the environment, and investment in conservation improves it. These two variable alter the rate of change as well as the steady state. We discuss the estimation of an equation like (2) in Section 5.4. Here we assume that all agents know the parameters of the equation. We assume that producers in country i in period t choose C_{it} and E_{it} to maximize

$$\mathcal{L}_{it} = \pi_{it} + \lambda_i[\alpha Z_{i,t}(K_0 - C_i + E_i^{\phi} - Z_{i,t}) + Z_{i,t}] \tag{3}$$

the sum of profits and $\lambda_i Z_{it+1}$, the value that producers impute to the environmental stock. The parameter λ_i measures the extent to which producers value the environmental stock. We could think of λ_i as a on the resource paid by producers, such as a stumpage fee in forestry. In that case, we would write the second term in (3) as $\lambda_i[z_{it+1} - z_{it}]$ to reflect the idea that producers pay for altering environmental quality; this would not change the results of the model. An alternate interpretation, which we adopt here, is that λ_i is the producers' shadow value of the resource. The magnitude of λ_i depends on (among other factors) the extent of producers' property rights. If $\lambda_i = 0$, producers have no property rights, and treat the environmental stock as a free good. As λ_i increases, producers place greater value on the stock. Therefore we view λ_i as an index of property rights. This provides a simple way of modeling institutional reform which changes the nature of property rights. In a more complete model, we would take the structure of property rights as fundamental, and treat the value of λ_i as endogenously determined through the solution to producers' dynamic optimization problems.[12] In that case, the equilibrium λ_i would depend on the values of Z_{1t} and Z_{2t}. Here we adopt the much simpler approach of taking λ_i as a known constant. The maximization of $\mathcal{L}_{it}$ gives the optimal values of C_{it} and E_{it}:

[12] Karp (1992) shows how this can be done for a particular structure of property rights under the assumption that producers are oligopolists.

$$C_{it}=\left[\frac{p_t\beta_2 Z_{i,t}^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{1}{1-\beta_2}} \tag{4}$$

$$E_{it}=\left[\frac{\lambda_i\alpha\phi Z_{i,t}}{1-s_i}\right]^{\frac{1}{1-\phi}} \tag{5}$$

Substituting equation (4) into the production function gives the supply for country i:

$$y_{it}=Z_{i,t}^{\beta_1}p_t^{\frac{\beta_2}{1-\beta_2}}\left[\frac{\beta_2 Z_{i,t}^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{\beta_2}{1-\beta_2}} \tag{6}$$

This equation has a constant elasticity of supply, but the location parameter of the function depends on the environmental stock and the index of property rights.

Oligopolistic processors in the North import the raw product and sell the finished product. They receive rent due to a fixed input (e.g. patent, brand name). The input is transformed into the final good using a constant returns to scale, Cobb-Douglas production function.

$$q=AF^{\gamma}(y_1+y_2)^{1-\gamma} \tag{7}$$

where q is the output of the final product, F is the fixed input, and y_i is the supply of raw material from Southern country i. Processors have some degree of market power in the input market[13]. They take $\bar{Q}$, the price they receive for the final product, as given, and their value of marginal product is $\bar{Q}\partial q/\partial y_i$. We model their market power using the equilibrium condition:

$$\frac{\bar{Q}\frac{\partial q}{\partial y}-\bar{p}}{\bar{p}}=M_c \tag{8}$$

[13] We could instead model processors' market power in the output market.

The price processors pay for the input is $\bar{p}$; this differs from the price Southern producers receive if there is a tariff. The percentage price mark-up in equation (8) is M_c. A value of $M_c = 0$ means that processors are price-takers in the input market. Positive values of M_c indicate monopsony power. Here we take M_c as an exogenous constant parameter. A more complicated model would begin with the game that the oligopsonistic processors play, and treat M_c as endogenous, deriving it from the equilibrium condition to the game. In that case, M_c would be a function of Z_{it} and would change over time. In order to simplify our results, we assign a specific value to M_c, $M_c = .1$. This means that processors mark-up the value of marginal product over price by 10%; we regard this as a moderate degree of oligopsony power.

Eliminating $\partial q/\partial y_i$ from equation (8), using the production function (7), and then using the supply function [equation (6)] in the result, gives us the equilibrium condition:

$$\bar{Q}^{\left(\frac{1-\beta_2}{1-\beta_2+\gamma\beta_2}\right)} H = \bar{p} \tag{9}$$

which uses the definition

$$H = \left[\frac{AF^{\gamma}(1-\gamma)(1+\tau_p)^{\frac{\gamma\beta_2}{1-\beta_2}}}{\left[1.1 \sum_{i=1,2} \left[Z_i^{\beta_1} \left[\beta_2 \frac{Z_i^{\beta_1}}{(1+\tau_i)w + \alpha\lambda_i Z_i} \right]^{\frac{\beta_2}{1-\beta_2}} \right] \right]^{\gamma}} \right]^{\frac{1-\beta_2}{1-\beta_2+\gamma\beta_2}} \tag{10}$$

In writing (9) we have also used the definitions $\bar{p} = (1+\tau_p)p$, where τ_p is the tariff, and $\bar{Q} = Q/(1+\tau_c)$, where τ_c is the sales tax.

In addition to oligopsony profits, processors earn rent for the fixed input *F*. This rent is f, given by:

$$f = \bar{Q}\left(\frac{\partial q}{\partial F}\right)\Bigg|_{F\ fixed} \tag{11}$$

The "representative consumer" in the North has a time-invariant constant elasticity of demand:

$$(1+\tau_c)\,\bar{Q} = Kq^{-\eta}\,. \tag{12}$$

After eliminating q from (12), using the production function and the supply function, we obtain the equilibrium condition:

$$(1+\tau_c)\bar{Q} = I\,\bar{p}^{\left(-\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}\right)} \tag{13}$$

which uses the definition

$$I = \frac{K(1+\tau_p)^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}{A^{\eta}F^{\eta\gamma}(1+\tau_c)\sum_{i=1,2}\left[Z_i^{\beta_1}\left[\frac{\beta_2 Z_i^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_i}\right]^{\frac{\beta_2}{1-\beta_2}}\right]^{\eta(1-\gamma)}}\,. \tag{14}$$

Equations (9) and (13) are two equations in the two unknowns, $\bar{p}$ and $\bar{Q}$. Solving these equations gives the equilibrium prices that processors pay and receive, $\bar{p}^*$ and $\bar{Q}^*$:

$$\bar{Q}^* = \left[\frac{I}{H^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}\right]^{\frac{1-\beta_2+\gamma\beta_2}{1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma)}} \tag{15}$$

and

$$\bar{p}^* = H\left[\frac{I}{H^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}\right]^{\frac{1-\beta_2}{1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma)}} \tag{16}$$

Finally, we can use these equilibrium prices, together with equations (4), (5) and (6), to obtain the equilibrium values:

$$C_i^* = \left[I^{1-\beta_2} H^{1-\beta_2+\gamma\beta_2}\right]^{\frac{1}{(1-\beta_2)(1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma))}} \left[\frac{\beta_2 Z_{i,t}^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{1}{1-\beta_2}} \tag{17}$$

$$E_i^* = \left[\frac{\lambda_i \alpha \phi Z_{i,t}}{1-s_i}\right]^{\frac{1}{1-\phi}} \tag{18}$$

$$y_i^* = Z_{i,t}^{\beta_1}\left[I^{1-\beta_2} H^{1-\beta_2+\gamma\beta_2}\right]^{\frac{\beta_2}{(1-\beta_2)(1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma))}} \left[\frac{\beta_2 Z_i^{\beta_1}}{(1+\tau_1)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{\beta_2}{1-\beta_2}} \tag{19}$$

Our model is designed to simulate the effects of policy on the dynamics of the environment, prices, trade, and welfare. This analysis requires numerical solutions. However, the model is simple enough to obtain a number of unambiguous comparative static results, reported in Table 5.2.

Table 5.2. Comparative Static Results

	$\bar{p}$	$\bar{Q}$	C_1	C_2	E_1	E_2	y_1	y_2
τ_1	+	+	-	+	0	0	+/-	+
τ_2	+	+	+	-	0	0	+	+/-
λ_1	+	+	-	+	+	0	-	+
λ_2	+	+	+	-	0	+	+	-
s_1	0	0	0	0	+	0	0	0
s_2	0	0	0	0	0	+	0	0
τ_p	+	+	-	-	0	0	-	-
τ_c	-	-	-	-	0	0	-	-
Z_1	-	-	+/-	-	+	0	+/-	-
Z_2	-	-	-	+/-	0	+	-	+/-

We see that increasing τ_1, τ_2, λ_1, λ_2 and τ_p increases producer and consumer prices. A consumption tax or an increase in the stock of environment decrease producer prices. Use of purchased inputs (chemicals) is decreasing in own tax, own property rights, consumption tax, tariff and the stock of environment of the rival nation. On the other hand, chemical use is increasing in the rival country's taxes and property rights. An increase in the environmental stock has an ambiguous effect on chemical use in the same country. Application of effort for environmental improvement is increasing in own property rights, subsidies and environmental stock. Supply in country i is decreasing in taxes, tariffs, consumption tax and the other country's environmental stock. Supply in country i increases with taxes and property rights of the other nation.

This model, in common with that of Chapter 4, incorporates the feature that reform in a country tends to be undercut by foreign competition. Chemical use and supply are increasing in the other country's taxes and property rights. By applying taxes or increasing property rights, a nation decreases its supply, thereby increasing market prices. This creates an incentive for the other country to increase supply by increasing its use of chemicals. The current level of conservation effort in a country does not depend on policy elsewhere. However, the model contains dynamic linkages, because policy in one country affects (via the price mechanism) the future environmental stock in its rival, and thus alters future conservation effort there.

For welfare analysis we calculate the stream of profits of the producers in the South, processors' rents (when F is normalized to 1) plus oligopoly profits, and consumer surplus in the North. The trajectories of these welfare measures depend on the initial condition of the environment and on policies. The net present value of producer profits, processor rents[14], and consumer surplus[15], with a horizon of T years, are

$$NPV\ \pi_i^* = \sum_{t=0}^{T} \left(\frac{1}{1+\rho} \right)^t \pi_{i,t}^* \qquad (20)$$

[14] In our numerical experiments we report processor rents which result from the presence of the fixed factor. We do not include oligopsony rents.

[15] When consumers' demand is inelastic (and constant), consumer surplus is infinite for any price. In measuring consumer welfare we calculate surplus as the integral between the equilibrium price Q^* and a (high) "choke price". This enables us to measure the change in consumer surplus due to any policy change.

$$NPV\ Rent = \sum_{t=0}^{T} \left(\frac{1}{1+\rho}\right)^t \bar{Q} \frac{\partial q_t}{\partial F}|_{F=1} \tag{21}$$

$$NPV\ Consumer\ Surplus = \sum_{t=0}^{T} \left(\frac{1}{1+\rho}\right)^t \int_{\bar{Q}_t^*}^{Choke} \frac{1}{Q^{-\eta}} dQ \tag{22}$$

5.3 Numerical Simulation

The comparative statics discussed in the previous section provide some information about the effect, within the same period, of policy changes. However, we have to simulate the model in order to estimate the magnitude of changes, and to trace out the dynamics. We show that internalization policies in the South can increase welfare in the North. We also use the model to illustrate a situation where a decision by one producing country to internalize costs may induce the competing producer to adopt a similar policy. This does not occur in a static model.

Parameter values used in the simulation appear in the last column of Table 5.1. For the parameters of the production functions (for Southern producers and Northern processors) and the demand equation, empirical literature enables us to choose values that are of "reasonable" orders of magnitude. However, it is much harder to know what constitutes a reasonable value for parameters of the growth equation and the index of property rights, λ_i. For example, although it is obvious that $\lambda_i = 0$ is a lower bound, we do not know what value of λ_i implies well-developed property rights. We experimented with a wide range of values to obtain results that seemed plausible. However, we can only interpret these results as illustrative of possible outcomes.

For the results we report, we varied λ_i, between 0 and .02, holding $\lambda_1 = \lambda_2$. For the base run we varied only λ_i, setting all of the taxes equal to zero. In subsequent experiments we set one tax or subsidy rate to 20%, holding other policy variables at zero, and we examined the effect of different values of λ_i. These experiments describe the effect of unilateral policy intervention under different property rights. We also analyze the impact of policy coordination in taxes/subsidies between the two Southern countries, by changing taxes in one country but not the other.

Figure 5.1 shows the path of the stock of environment under property rights equaling 0, .01 and .02. The stock of environment begins at the undisturbed steady state, $K_o = 8$, and monotonically decreases over time. With human intervention, property rights play a significant role in deciding the steady state level of environment. Existence of property rights forces the producers to account for the future value of the environment. With zero property rights the steady state of Z is 5.3; the steady state is 6.4 when the property rights parameter is .02.

The supply (Figure 5.2) of raw material decreases over time because of decreasing environmental stock.[16] The supply path for $\lambda = 0$ crosses the paths for $\lambda > 0$. For given Z, the absence of property rights ($\lambda_i = 0$), leads to a larger initial supply, but supply falls more quickly as the environment is degraded (relative to the case for $\lambda > 0$). This fact is reflected in the prices also. Initially the prices for λ=0 are lower than $\lambda > 0$, but this comparison is reversed later. The steady state level of supply for λ equal to 0, .01, and .02, respectively, is 3.2, 3.4 and 3.3. The steady state stock is monotonically increasing in λ, but the steady state supply is first increasing and then decreasing. This non-monotonicity of supply is due to the fact that an increase in λ tends to increase long run supply via its effect on the stock, but it tends to reduce supply because it leads to lower use of inputs.

Table 5.3 compares the present discounted value of consumer surplus, profits of the producer in one Southern country (Country 1), and the processors' rent. The interests of consumers and processors tend to be aligned, since both groups benefit from low prices of the primary good. Their welfare is highest at intermediate values of λ. (Of course, their interests are not perfectly aligned, so there is no reason for the two welfare measures to reach a maximum at the same value of λ.) The North benefits from some internalization in the South, since this protects their long-run supply. Southern producers' profits continue to increase with larger values of λ. Increased internalization leads producers to decrease supply, which increases price and the flow of profits. Internalization provides a partial substitute for a producer cartel. Both the North and South benefit from some level of internalization, but the optimal level is greater for the South. This result depends on the assumption of very inelastic demand. We took another extreme case, in which the demand elasticity was equal to 4, rather than .25. In that case, the value of λ that maximizes the present discounted value of profits in the South is lower than the value that maximizes Northern welfare. Thus, whether the North or the South has the greater interest in internalization policies, depends to a large extent on the elasticity of demand.

[16] If the initial value of Z had been small, and the index of property rights large, there would have been significant investment in conservation. This would have led to increasing Z and increasing supply over time.

Table 5.3. Present Discounted Value (NPV) of Flow Variables: Base Case

Property Rights	0	.01	.02
NPV CS	31.59	32.19	30.30
NPV Profit 1	3.2148	3.3977	3.6027
NPV Rent	39.155	39.209	38.932
Steady State Y1	3.168	3.3664	3.3435
Steady State Z1	5.288	6.0168	6.4375

Over time, the flow of processor rents and consumer surplus falls, as price rises. Profits in the South also fall: the increased price is not sufficient to offset the increase in costs due to lower environmental stock. Nevertheless, it might still be in the producers' interests to create an "artificial shortage" of the primary good by damaging the environment. This possibility does not arise in our model because the benefit (from the standpoint of producers) of a future shortage comes at the cost of a current glut. However, policies which discourage conservation effort may actually benefit the South, since those policies lead to decreased future supply, without increasing current supply.

An increase in the index of property rights affects the steady state level of chemical use in three ways. For our simulations, the net effect of an increase in λ is to decrease steady state use of chemicals. As λ increases, producers increasingly internalize the damage done by inputs, and therefore use less of them. This leads to improvement in the environment. Since the environment and inputs are substitutes in production, this secondary effect also reduces the demand for inputs. The third long-run effect is due to a change in price, which changes the value of marginal product of inputs. We have seen that the long-run effect of an increase in λ on primary price is ambiguous. If price falls in the long run, this further reduces the demand for inputs. If price rises, this increases the value of the marginal product of inputs and tends to offset the first two effects. In our simulations, this third effect was not strong enough to lead to a net increase in input demand, but we can not rule out that possibility. An increase in λ also leads to increased conservation effort, as expected.

Tables 5.4 through 5.6 and Figures 5.3 and 5.4 summarize the effects of changes in input taxes or a tariff. We consider three scenarios: Only one country in the South imposes a 20% input tax (Table 5.4); both countries impose the tax (Table 5.5); the North imposes a 20% tariff (Table 5.6). The welfare measures we report do not include tax/tariff revenues, although it would be straightforward to include these.

The most striking result, illustrated in Figures 5.3 and 5.4, concerns the relation between the index of property rights and the tax/trade policy. We noted that in the absence of those policies, consumers in the North preferred "moderate" property rights in the South. However, under either a tariff or an input tax, the present discounted value of consumer welfare is highest when there are no property rights. This provides an example of how one policy reform changes incentives for reform of other policies. If there are no property rights in the South, consumer surplus in the North is increased by either a tariff or an input tax, because of the long run effects of these policies on the environment. If property rights in the South are moderate or strong, both the tariff and the tax policies reduce consumer welfare. The situation is very different in the South, where neither policy alters incentive to improve property rights.

Both the North and South prefer an input tax over the tariff. This is an example of the "Principle of Targeting", which asserts that policies should attack distortions as directly as possible. The preference for the tax rather than the tariff is more pronounced in the North, the stronger are property rights in the South. Both policies increase the steady state environmental stock. The tariff is slightly more effective, and this difference increases with the index of property rights. However, the two policies have very similar effects on the steady state environment (Tables 5.5 and 5.6).

It is worth noting that when property rights in the South are very weak, the North benefits from imposing a tariff. This is only because the tariff ameliorates the production distortion in the South. The welfare improvement for the North resulting from the tariff has nothing to do with the usual optimal tariff argument. Our measure of consumer benefits excludes tariff revenues (and the Meltzer Paradox does not arise[17]). When property rights in the South are strong, so that the externality is not important, the tariff harms Northern consumers.

[17] This paradox arises when a tariff causes such a large fall in the world price that the domestic (tariff-inclusive) price of the importing country also falls.

Table 5.4. Unilateral Tax Policy in South: $\tau_1 = .2$, $\tau_2 = 0$

Property Rights (λ_i)	0	.01	.02
NPV CS	32.04	31.68	29.64
NPV Profit 1	3.2067	3.3837	3.5801
NPV Profit 2	3.1911	3.3837	3.6476
NPV Rent	39.207	39.137	38.835
Steady State Y1	3.3598	3.3563	3.3180
Steady State Y2	3.3227	3.3666	3.3456
Steady State Z1	5.7566	6.2906	6.6128
Steady State Z2	5.3377	6.0074	6.4193

Table 5.5. Multilateral Tax Policy in South: $\tau_1 = \tau_2 = .2$

Property Rights (λ_i)	0	.01	.02
NPV CS	32.40	31.25	28.97
NPV Profit 1	3.1857	3.4110	3.6238
NPV Rent	39.255	39.069	38.740
Steady State Y1	3.3615	3.3568	3.3209
Steady State Z1	5.7923	6.2835	6.5974

Table 5.6: Trade Policy Intervention from North: $\tau_p = .2$

Property Rights (λ_i)	0	.01	.02
NPV CS	32.40	30.85	27.96
NPV Profit 1	2.6549	2.8793	3.0859
NPV Rent	39.255	39.009	38.597
Steady State Y1	3.3615	3.3511	3.3032
Steady State Z1	5.7925	6.3567	6.6913

Comparison of Tables 5.3-5.5 illustrates the different effects of no policy intervention, unilateral intervention, and multilateral intervention (in the South). For all values of λ, imposition of a unilateral input tax in Country 1 improves the steady state environmental quality there, and causes it to worsen in Country 2. A unilateral tax increases average steady state environmental quality (but by less than would a multilateral tax). This model is consistent with the popular view that unilateral internalization efforts suffer from the problem of "leakage": some environmental damage merely moves abroad. (In other words, internalization policies in Country 1 exacerbate the externality in Country 2. This is the leakage effect.) This leakage is usually thought to be less than 100%, as is the case in our model. Unilateral intervention reduces the net present value of profits in Country 1. This is also consistent with the widespread view that countries which attempt unilateral internalization will bear economic costs.

However, we see that when property rights are weak (λ equals 0 or .01), unilateral internalization in Country 1 *reduces* the net present value of profits of its rival. This is contrary to the traditional view that internalization in one country necessarily benefits competing exporters. The traditional view is based on a static model, in which an inward shift in one country's supply function (resulting from internalization) increases world price and benefits other exporters. In a dynamic model, however, this occurs only in the first stages. In later stages, Country 1's internalization policy leads to an increase in its environmental stock, and thus possibly increases its supply function. (Whether supply increases depends on how important to production the environment is, relative to purchased inputs.) When Country 1's steady state supply function shifts out, this harms the rival country, which, in addition has suffered from a deterioration in its environment (the leakage effect). Since Country 2's welfare depends on the stream of its profits, it is not surprising that the welfare effects are ambiguous (and may even be 0, as is the case for $\lambda = .01$).

If $\lambda = 0$, Country 2 is worse off when Country 1 imposes a unilateral tax, but both Southern countries are even worse off if Country 2 imitates the policy. For $\lambda = .01$, both Southern countries are worse off when Country 1 pursues unilateral internalization policies. But in this case, Country 2 is better off following suit. In the language of game theory, there are two non-cooperative Nash equilibria[18] when $\lambda = .01$: neither country imposes the tax, or both countries impose the tax. In our example, the second equilibria leads to higher (economic) welfare, and improved environment.

[18] In this game each country has two actions: a zero tax or a 20% tax. The payoffs associated with the policies are shown in Tables 5.3-5.5.

The possibility described above has important implications for the way in which we view unilateral internalization policies. (We discussed this issue in a different context in Chapter 2.2.) The traditional view, as we saw, is that unilateral internalization policies impose economic costs on the internalizing country, and confer benefits on competing exporters. Moreover, even if one country does pursue internalization policies, competing exporters will not want to follow suit, because this would erode the benefits they had obtained. If this view is correct, there is a (*narrow*) economic argument for not internalizing externalities, or for backing away from such policies if they had been imposed in the past. This view is based on a static model. We have seen that in a dynamic model, a completely different configuration of incentives arises in a natural way. If competing exporters are committed to avoid using internalization policies, it is rational for one country to avoid them as well. (This is the first Nash equilibrium we mentioned above.) However, that commitment is not rational, since it would be in the best interest of competing exporters to follow the lead of the internalizing country. Knowing this, it is rational for any country to take the lead, and begin with internalization policies, confident that its rivals will follow suit. This is an example of where internalization policies are *strategic complements*. Of the two Nash equilibria we identified, the one that involves internalization by both Southern countries seems the most plausible.

In this Section we discussed a number of possible results arising from internalization policies. There are of course other policy configurations that we could analyze, such as changes in subsidies for conservation effort, or the use of consumer taxes rather than tariffs. The experiments we described demonstrate the potential of the model. The model can assist in quantifying the effects of policies. It also can help us to improve our intuition about the effect of internalization policies in a dynamic setting.

5.4 Estimation of the Model

Our model would be much more useful for policy analysis if we had a better idea of the likely magnitude of the parameters. We have seen that a wide variety of outcomes, with very different policy implications, are possible. This model is difficult but not impossible to estimate. This section suggests a practical approach.

Many features of our model are standard. We have demand equations for the input (C) the intermediate product (y), and for the final product. We have supply equations for the intermediate and the final product. These equations are linked to a production function for the intermediate-good and the final product. Thus we have a simultaneous equations model. This is already a non-trivial estimation problem, but it is a familiar one. Our model is substantially complicated by the presence of the unobserved state variable, Z. This variable enters the production function, and therefore also enters the input demand function and the intermediate-good supply function. The "novel" feature of our model, from the standpoint of estimation, is that it involves an unknown variable which changes endogenously.

In order to concentrate on this feature, we consider a simplified version of the model which includes only a state equation such as equation (2) and a production function. Suppose that we were able to use these equations to estimate Z_t and the parameters of the state equation. We could then also estimate the other parameters of the model, including the index of property rights, λ. To see this, note that λ appears in the input demand equation and the effort equation, multiplied by αZ [Equations (4) and (5)]. If we had an estimate of αZ, we could use (4) and (5) to identify the parameter λ. Therefore we consider that the fundamental estimation problem lies in the estimation of the parameters of the state equation and the time series of the state. Golan, Judge and Karp (1994), study exactly this estimation problem; we describe their approach.

We begin by noting the similarity between our problem and the problem of estimating an unobserved state given noisy observations. That model consists of two equations. The observation equation is

$$y_t = f(z_t, x_{1t}, \varepsilon_{1t}; \beta_1) \ . \tag{23}$$

The unobserved state variable at time t is z_t; the scalar y_t and the vector of explanatory variables x_{1t} are observed; ε_{1t} is a scalar random variable, and β_1 is a vector of unknown constant parameters. The state equation, which describes the evolution of z, is

$$z_{t+1} - z_t = g(z_t, x_{2t}, \varepsilon_{2t}; \beta_2) \ . \tag{24}$$

The vector of observable variables x_{2t} may contain y_t and elements of x_{1t}; ε_{2t} is a scalar random variable, and β_2 is a vector of unknown constant parameters. Equations (23) and (24) are the stochastic versions of the production function implicit in (1) and the state equation (2). The problem is to estimate the unobserved values of the state variable, z_t, and the vector of parameters, $\beta = (\beta_1, \beta_2)$.

This model obviously encompasses many special cases. The interpretation that interests us is the following. We observe the output of an agricultural commodity, y, which depends on the index of "environmental quality", and inputs such as chemicals and labor (elements of x_1). We observe the inputs, but not the quality index. The evolution this index depends on some inputs which also effect output in the current period (e.g. chemicals), and on other factors such as investment in drainage. We think of z as an index of environmental quality, but this index also incorporates physical capital. From the standpoint of production, there may be no clear distinction between environmental and physical capital. An advantage of our approach is that it does not require that we make this distinction.

In the simplest case, the random variable ε_2 is absent, so that (24) is deterministic. Then we can use (24) to solve for z_t in terms of an initial condition z_o and $\{x_{21}, x_{22},...x_{2,t-1}\}$. Substituting the result into (23) gives y as a function of z_o, $\{x_{21}, x_{22},...x_{2,t-1}\}$, x_{1t}, β and ε_{1t}. Even if ε_2 is present, we can use equation (23) to eliminate z_t. Upon substitution, however, we obtain a new random variable in equation (23). The resulting covariance structure would be extremely complicated, involving autocorrelation and heteroscedasticity, and the unknown vector β. At the very least, this would be a daunting numerical problem. We could also try to estimate (23) and (24) using filters, such as the Kalman filter/maximum likelihood. There are some statistical problems with this approach, but even more serious is that the resulting numerical problem is extremely formidable.

We therefore seek an alternative estimation strategy that is theoretically defensible and which is *practical to implement.* Golan et al. formulate the estimation problem as a maximum entropy problem. Using Monte Carlo experiments, they show that the model can be estimated quite easily. In addition, the estimation results are promising: the parameters of (23) and (24) and the unobserved values of z were estimated with a moderate to high degree of accuracy.

In view of these results, we think that it is possible to obtain useful estimates of our model. This is an important topic for future research.

5.5 Conclusion

We formulated a dynamic model of North-South trade. Current production decisions determine current supply and the change in an index of environmental quality. The latter determines future supply. We used a simple device to model the production externality, the severity which was described by an index of property rights.

We studied the qualitative relation between the production externality, a variety of policies, and welfare measures for different agents. In a global market all regions share the cost and benefits of internalization; our model allows us to simulate the distributional consequences of policies. We emphasized why a dynamic model and a static model can lead to different policy conclusions. This difference is particularly pronounced when we examine the problems of unilateral internalization policies. Static models emphasize the difficulty of using unilateral policies. Dynamic models help us understand why adoption of such policies may be attractive.

Throughout this chapter we have maintained a narrow measure of welfare, which consists of consumer surplus for consumers, and profits or rent for producers. We recognize that the change in the environment confers many other costs and benefits on society. However, we think that the (narrow) economic costs and benefits are important, and perhaps are not closely related to broader considerations. It is therefore useful to have a model which isolates the narrow costs and benefits. In principal, it would be a simple matter to include in our welfare measures other functions of the environment which would capture the broader considerations. As we saw from our review in Chapter 3, in practice it is very difficult to measure the social cost of environmental damage.

There are three directions in which we think it is profitable to pursue further research. First, there are many aspects of our model which we have not yet unexplored. We have not yet examined the importance of processors' oligopoly power, or the potential to use effort subsidies. We have not examined the importance of asymmetries of technology or institutional setting (as measured by the index of property rights) in the South. We have not included the revenue effects of the taxes. For example, we could modify the model to have input taxes returned in the form of an effort subsidy, so that the two policies are revenue neutral. We also need to perform more extensive sensitivity studies on our parameters.

Second, we think that the model points to theoretical work which can help clarify the issue of unilateral v. multilateral internalization policies. We outlined the main ideas in our discussion of strategic substitutes and complements, but the development of these ideas is far from complete.

Third, we think there is a potential to provide this model with an empirical base. Preliminary work on similar estimation problems provides grounds for optimism.

Figure 5.1: Stock of Environment

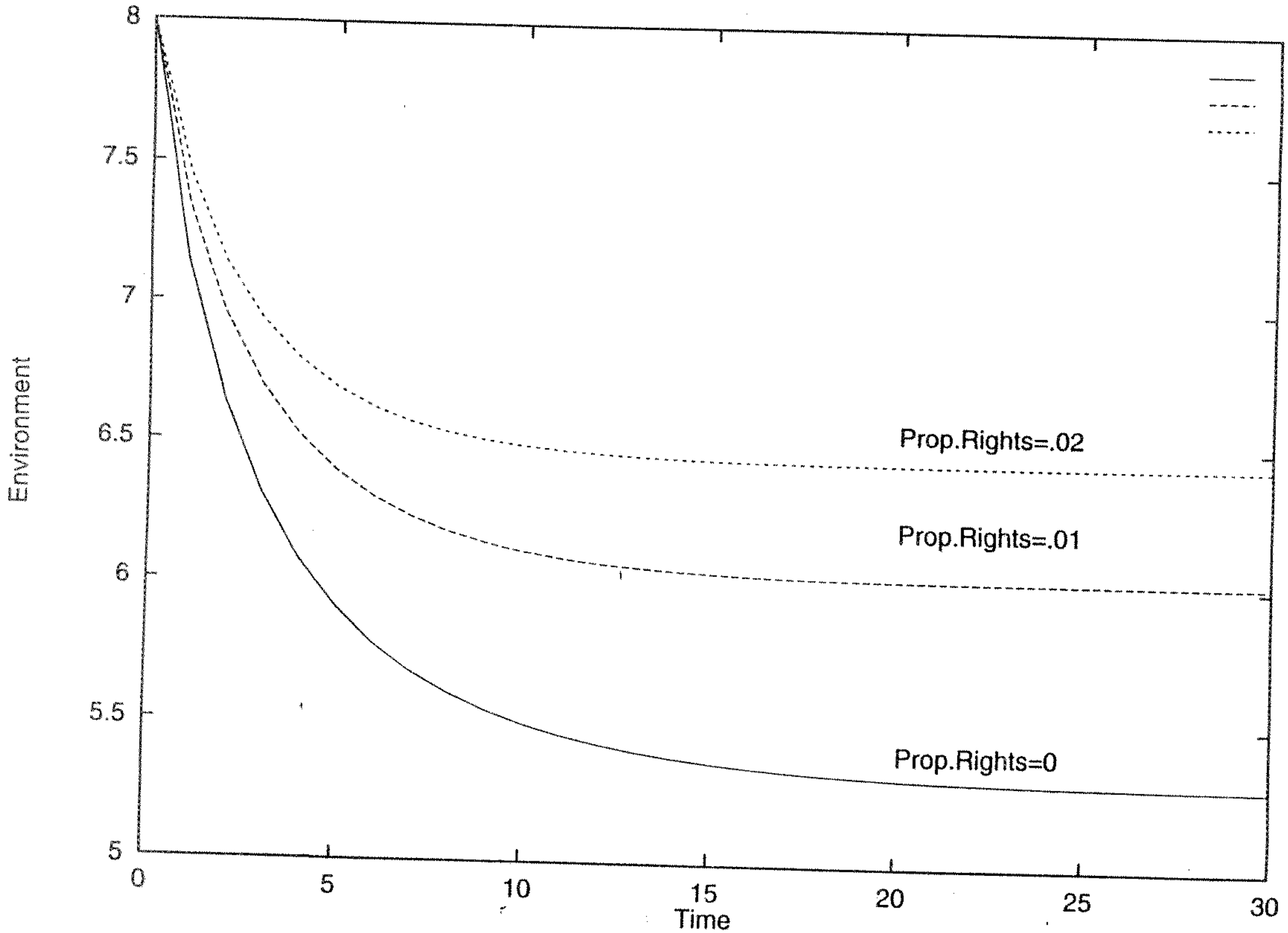


Figure 5.2: Supply of Raw Material from South

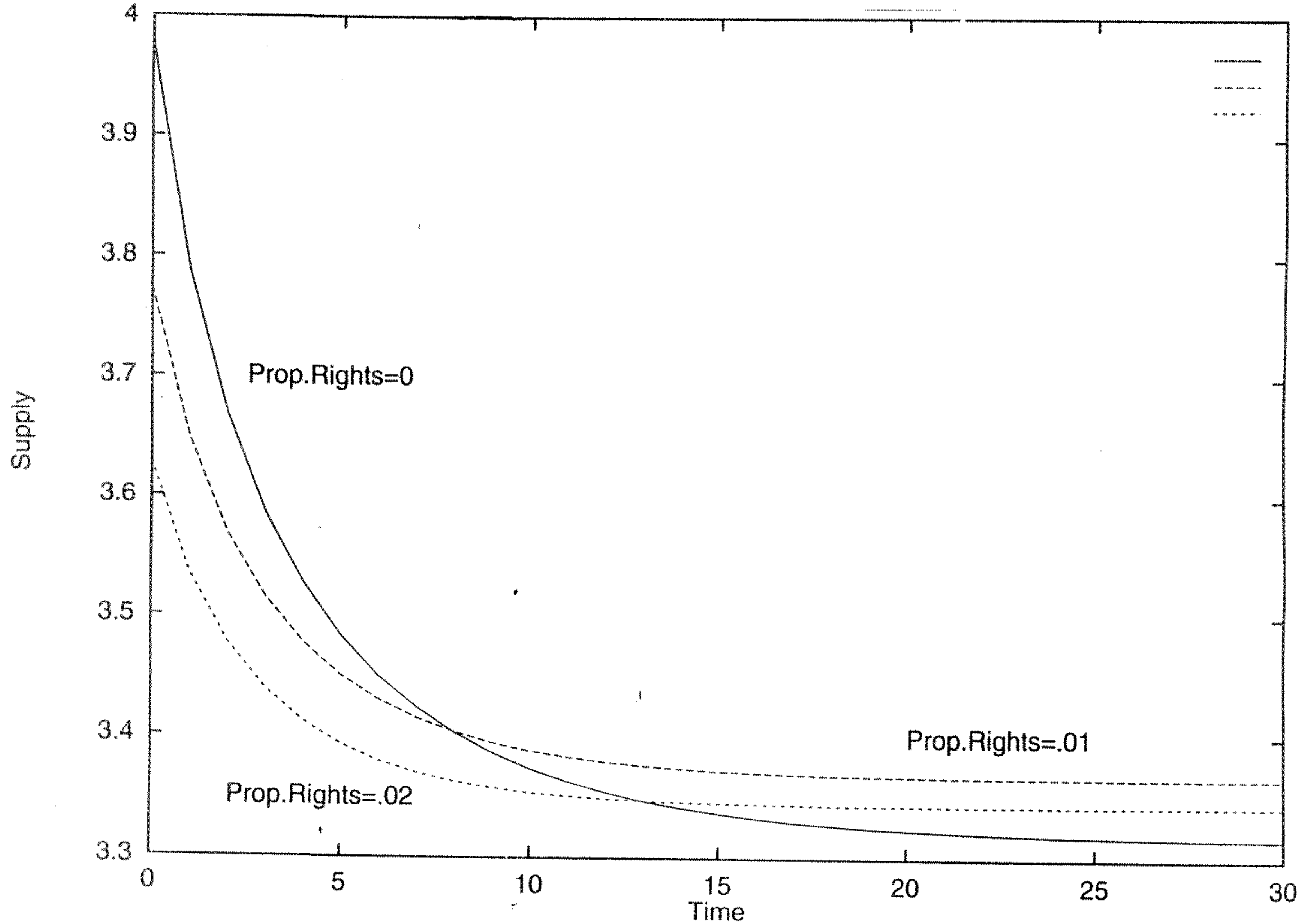


Figure 5.3: Net Present Value of Consumer Surplus

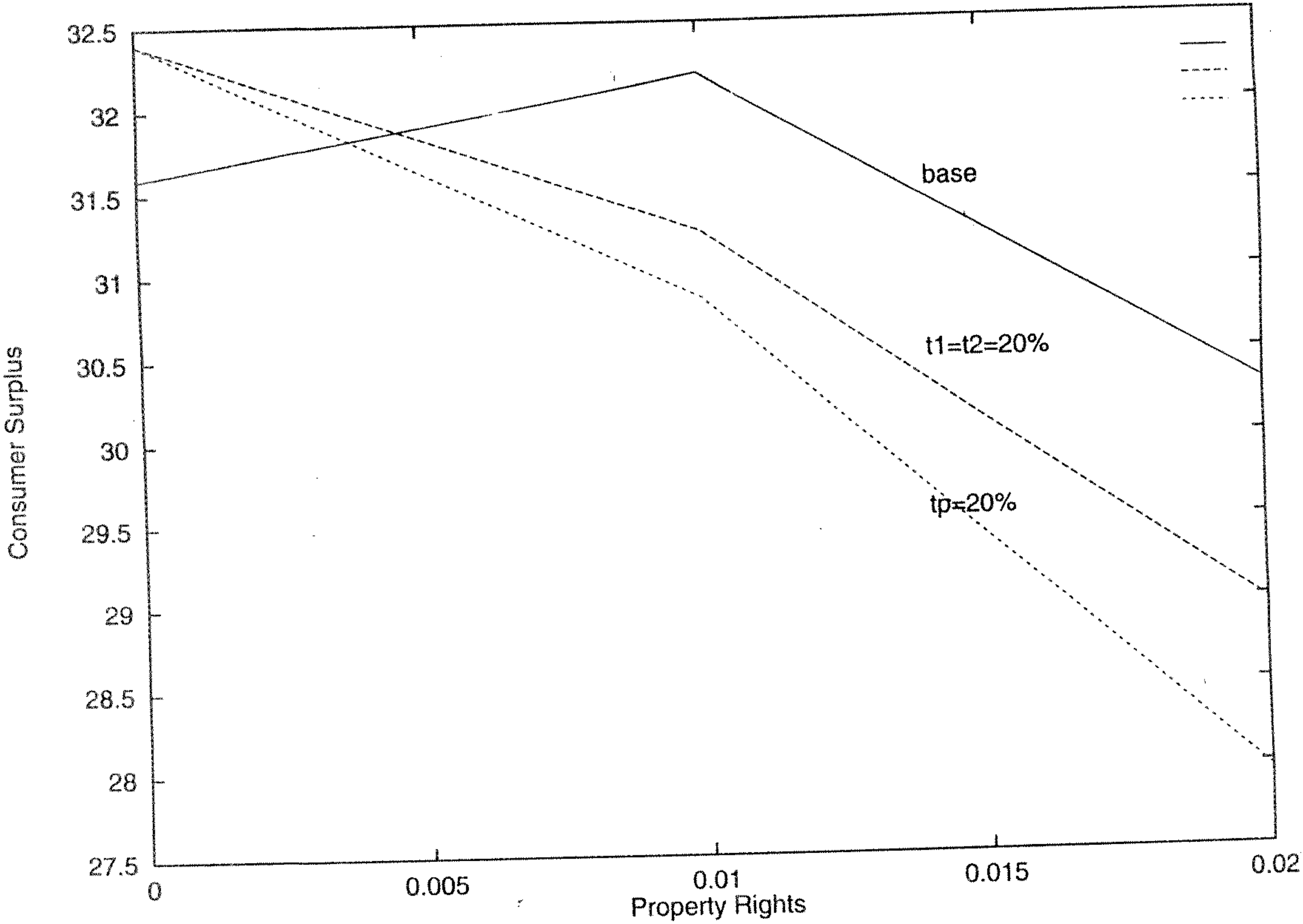
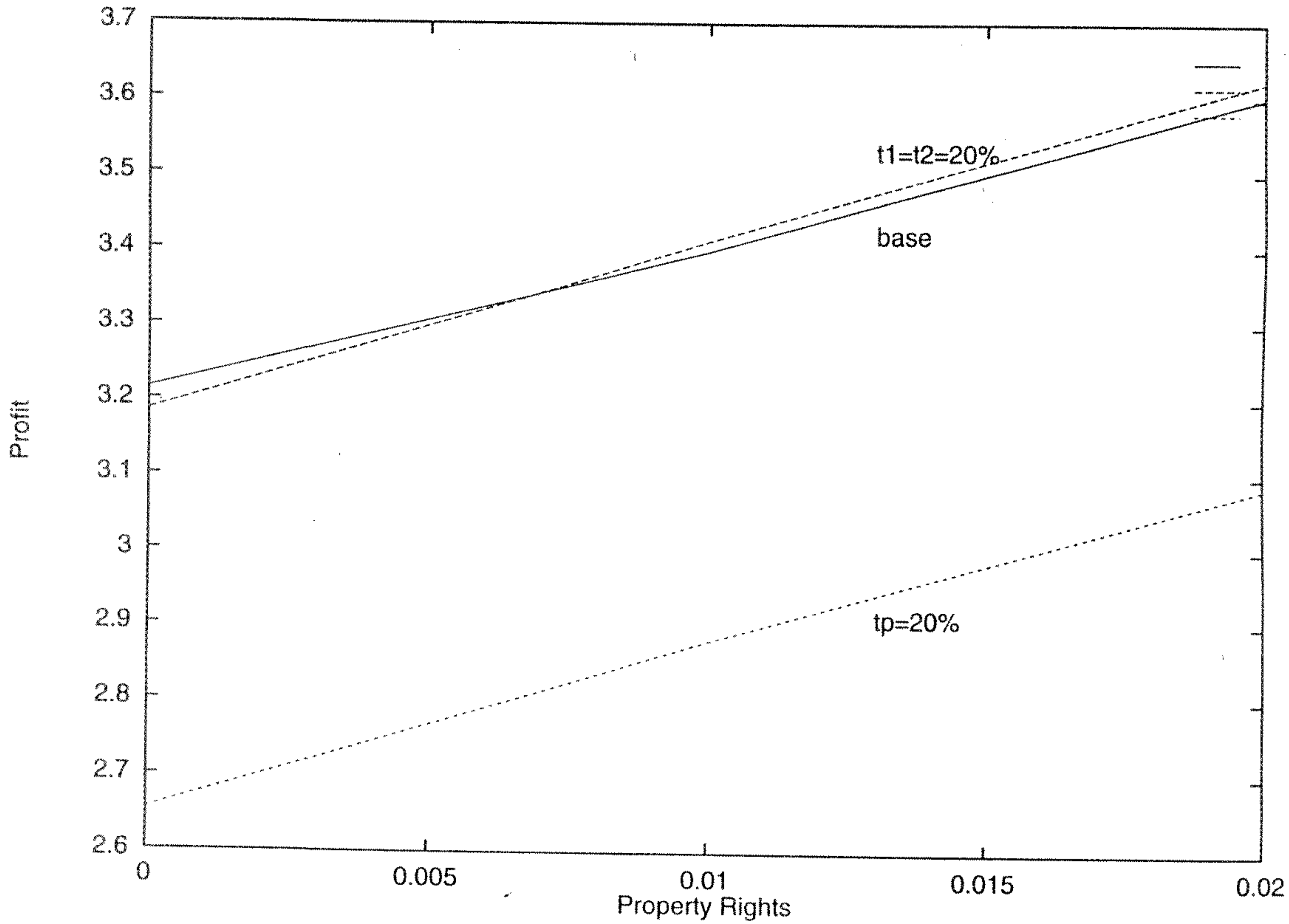


Figure 5.4: Net Present Value of Producer Profits



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6. Conclusion

We proceeded along four lines in attempting to contribute to the synthesis of the study of international trade policy and environmental policy. First, we discussed several major issues regarding internalization policy and international trade. Second, we reviewed the state of knowledge concerning the extent of environmental damages caused by agriculture, and we summarized current and proposed policies. Third, we used a standard international trade model to estimate the effects on prices, production, and trade flows of several internalization policies. Fourth, we analyzed a dynamic trade model in which the environment is an explicit factor of production.

There is probably some truth to the belief that foreign competition tends to undercut domestic internalization policies, but the popular view overstates the magnitude of the relation. Both theory and empirical evidence suggest that even fairly significant internalization policies lead to small losses in market share and ambiguous changes in export revenue.

Most of the theory of environmental regulation has been developed for developed market economies where behavior is determined largely by price signals. In poorer countries, income constraints loom larger. There, using only price policies, in the absence of transfers, might result in continued impoverishment of the world's most vulnerable, and continued environmental degradation.

Although trade is not the cause of environmental problems, trade policy can be used to remedy them. However, general trade restrictions are as likely to harm the environment as benefit it. Trade restrictions which are narrowly targeted to environmental objectives can in principal improve both the environment and economic welfare, but it is more likely that the goals of environmentalists and protectionists would become confused. International trade and environment agreements, such as ICREAs, are more likely to accomplish useful goals. However, they offer little scope for major improvements and may divert the attention of policymakers from more promising remedies.

Choosing efficient internalization charges requires knowing the marginal environmental damage associated with an activity. Our review of damage estimates in Chapter 3 showed how difficult it is to obtain this information. In view of the variation in environmental damages across time and geography, it would be difficult, even in principle, to estimate marginal damages. However, we have general descriptions of types of damages related to different activities, and in some cases estimates of total damages. This information can be used to assess the likely order of magnitude of efficient policies: should they be large or small?

It is certainly important to institute policies that cause producers to internalize environmental costs. A more immediate goal should be to reform policies that create or exacerbate externalities. Many of these policies, such as fertilizer subsidies or price supports, are intended as indirect income transfers to producers. They are inefficient transfers, and lead to significant environmental damage.

Policy choice is complicated by ecological complexity. There are tradeoffs not only between environmental and economic objectives, but also among different environmental objectives. For example, establishing a vegetative ground-cover may reduce nitrogen in surface run-off and increase it in groundwater. These tradeoffs have to be weighed in determining policy. Environmental dynamics effect the timing of policy intervention. In some cases it is important to intervene before the level of environmental damages exceed a threshold, i.e. when the costs are still small. It may be difficult to obtain public support to remedy what appear to be small problems.

Most environmental policies directed at agricultural-related problems have been very limited in scope, focusing on particular problems in particular geographic locations. They typically do not consider the interaction of a specific problem with other environmental, economic and social issues, and they are designed to end after meeting narrow goals. We need to move toward a comprehensive view of environmental policy.

We showed how a standard trade model can be used to estimate the international economic effects of internalization policies. We described the markets for coffee, sugar and cotton, in order to give the reader perspective by which to judge the realism of our empirical model. Our review of the empirical literature showed the extent of disagreement about the probable magnitude of important parameters in the model. With this background, we were skeptical of the prospects of obtaining reliable estimates of the international effects of internalization policies. Nevertheless, we think that a formal model gives us a better idea of likely outcomes than does casual reasoning.

Simulations illustrate the types of results that a static, partial equilibrium, multi-commodity model is likely to generate. These results were broadly consistent with a simpler model that we had described in Chapter 2. Even quite large taxes have modest effects on prices and trade flows.

Among the important limitations of this model are the fact that it is static and the environment is not explicitly included. To address these limitations, we formulated and analyzed a dynamic single commodity trade model in which the environment is an explicit factor of production. We emphasized why a dynamic model and a static model can lead to different conclusions, such as those involving the problems of unilateral internalization policies. Static models emphasize the difficulty of using unilateral policies. Dynamic models help us understand why adoption of such policies may be attractive. We studied the qualitative relation between the production externality, a variety of policies, and welfare measures for different agents and we simulated the equity consequences of policies, both across nations and over time.

Our original objective in undertaking this project was to promote the development and synthesis of two fields of enquiry, the study of trade policy and environmental policy. This requires that economists and environmentalists have a better understanding of the accomplishments and the limitations in the two fields, and this is largely a matter of communication and education. Existing economic models and existing environmental measures can be used to evaluate policy proposals. We can, however, improve both the models and the measures. This improvement is more likely to occur as the two fields draw closer together.