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INTERNALIZATION OF ENVIRONMENTAL DAMAGES IN AGRICULTURE

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with

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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, concern has emerged 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. Since it is hard to monitor the actions of tens of thousands of farmers or to measure the amount of damage they cause, it is also difficult to control their behaviour 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 damage the local or national environment, for example water pollution or soil erosion. Many of these local problems also have an international dimension. For example, increasing the area planted with 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. Secondly, for many of the environmental problems associated with agriculture, the national damages are more significant than the global ones. Thirdly, 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 labour 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, 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 loses, 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. Since nations are unable to afford this loss of competitiveness, internalization policies require concerted multinational actions, so that all producers face the same cost increases. It is argued that trade makes unilateral internalization less effective, 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 or developing countries. Part of the reason why 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 developing countries. 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 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, chapter 3 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 that are important to policy-makers.

Chapter 4 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 labour, 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 3. 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, for example 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.

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 3, 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.

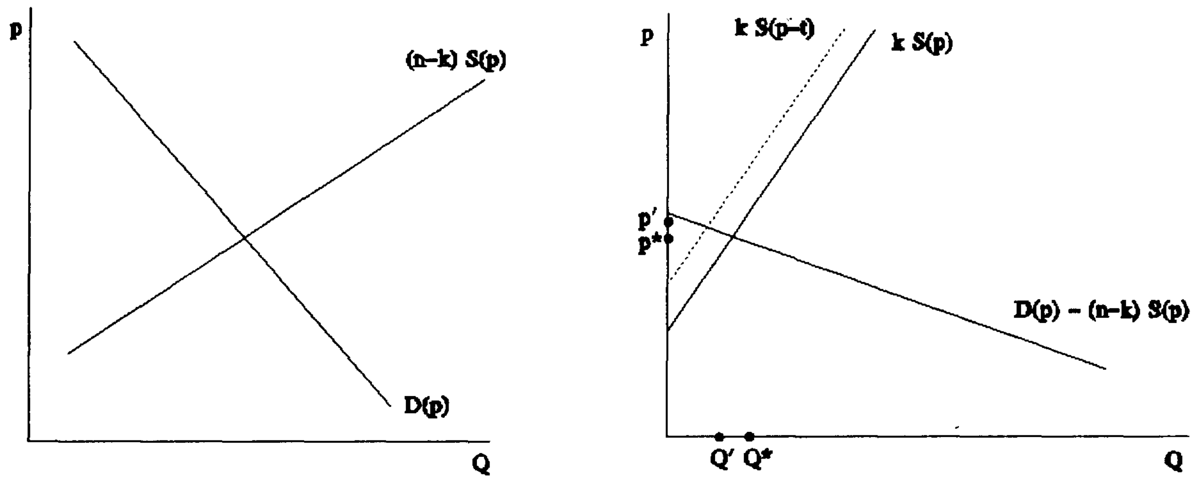

Figure 2.1a-b Equilibrium Effects of a Tax

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

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

With S(p-t) as the equilibrium supply of one of the k producers, we can write R = pS(p-t) as 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

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

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

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

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, η_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 (η_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.

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

	$\hat{M}$	$\hat{R}$	$\hat{P}$	$\hat{M}$	$\hat{R}$	$\hat{P}$	$\hat{M}$	$\hat{R}$	$\hat{P}$
η_s \ 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

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

In the previous section 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, but (ii) 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 behaviour 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.

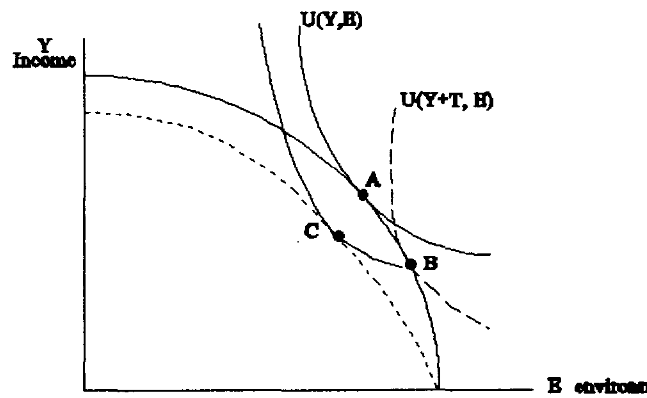

Figure 2.2

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 behaviour. 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 3, 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 behaviour 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, R. When the world price is P, it must export E to satisfy $P \cdot E = R$. A reduction in world price requires an increase in exports to satisfy this constraint. This model is too simple because R is not exogenous. However, a common hypothesis

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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.

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).

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 4.3 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 invalidate) such a statement, it has a ring of plausibility: international attention has been focused 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

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[2] We discuss this principal again in Chapter 4

[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.

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.

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

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

support. Other motives include 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.

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 4 develops the model sketched in Figure 2.3.)

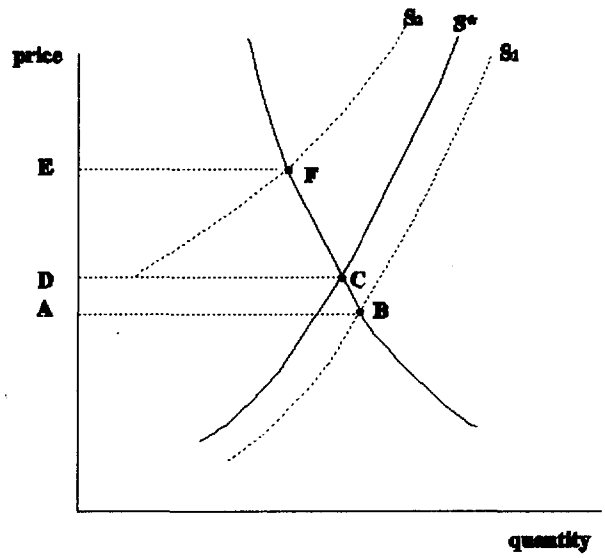

Figure 2.3

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 favour 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 association 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 3 (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 among 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 United States. 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.

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

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

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. ANALYSIS OF INTERNALIZATION USING A STATIC TRADE MODEL

3.1 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 2.2 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 3.2 presents a synopsis of world markets for our three commodities. Section 3.3 reviews existing trade models for these commodities. Section 3.4 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 3.5 we discuss the usefulness, for the purpose of policy analysis, of this sort of model, and we suggest directions for future research.

3.2 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 3.1 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

Table 3.1 Characteristics of the world markets of coffee, sugar, and cotton (1991)

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

Note: Share data and concentration data are calculated based on quantity data from UNCTAD (1993). Developing countries 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.

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 decreased slightly over the previous decade. The magnitude of this index is similar for the three commodities, for the late 1980s and early 1990s.

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%), United States (20%) and Japan (7%) accounted for more than half of world consumption. Per capita con-sumption in the US has shown a constant decline since the 1960s 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. Owing to the 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).

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

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) pro-viding 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 United States 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 United States 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).

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)

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[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).

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 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.

Developing countries account for most of the recent increase in

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

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 developing countries 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 1980s. 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 United States 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 1950s through the 1980s;

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 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 United States (18%).

Consumption: World consumption grew steadily, following growth in world population and increased per capita consumption in the developing countries 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 fibres has been limited by the rate of technology diffusion.

Trade and price: Although developing countries 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%.

3.3 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

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

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 3.2)

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 3.3)

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 United States cotton is produced largely without irrigation and is readily substitutable for other crops. Therefore, their estimate of United States cotton supply elasticity is higher than that of LDCs and CPNs. Duffy et al. (1987) estimate United States short-run supply elasticity and obtain a result similar to Monke and Taylor's (1985) estimate of world supply elasticity, approximately 0.37. However, the world long-run elasticity estimated by Monke and Taylor is much higher than the Duffy estimate of United States 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 non-responsive 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 United States fibre demands. The potentials for substituting synthetic fibers are considerably smaller in the LDCs than in the DCs. The estimates show that the United States 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 3.4)

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 3.2 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 3.3 Elasticity estimates for cotton

	Comment	Demand			Supply		Cross-price
		short-run	long-run	income	short-run	long-run	
1	Latin America	-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 LDC	-0.2	-0.44 -0.18	1 0.5	 0.07	1.35 0.77	
5	EC10 Japan Korea ROW World	2.7475 0.9780 0.1201 0.8110 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 Manmade fiber	-0.617 -0.431					
12	Japan Nicaragua U.S. Egypt USSR France Turkey U.S. Egypt USSR Hong Kong U.S. Pakistan USSR		 -15.5 -0.1 -1.19 -2.24 -8.33 -16.45 -0.73 -6.02 -8.01 -14.72 -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 3.4. 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.

3.4 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[10] 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

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

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[10]Karp, Larry with Chris Dumas, Bonwoo Koo and Sandeep Sacheti, "Review of environmental damage estimates in agriculture and internalization measures", UNCTAD/COM/52.

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).

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

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

$$\epsilon_f^M = \epsilon_f^H + \Sigma_j \epsilon_{sj} \epsilon_{cj}$$

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.

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

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.[11] In each case, we compare the effects of a 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 3.5 (price effects), 3.6 (production effects), and 3.7 (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 3.5-3.7.

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

[11] 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.

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 3.5 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 3.6 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)

Table 3.7 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	-121.072
EU	-113.565 (-113.203)	-88.320 (-90.145)	(-209.040)	(-204.372)
LA	-28.965 (-27.629)	30.651 (32.385)	-40.597 (-54.388)	-50.844 (-61.424)
AS	86.804 (86.163)	38.171 (39.168)	12.868 (10.746)	44.633 (42.112)
AF	-234.047 (-232.351)	126.955 (124.745)	34.211 (47.701)	22.223 (33.072)
			-257.808	437.372 (397.502)
			(-323.347)	

3.5 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.[12] 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 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

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

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 real 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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4. A DYNAMIC NORTH-SOUTH MODEL OF TRADE AND THE ENVIRONMENT

4.1 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 analyse 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: (i) The South consists of two regions, possibly with different policies and physical characteristics (technology and the environment). (ii) 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 4.2 presents the model formally and describes its qualitative properties. In Section 4.3 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 4.4, and provide concluding comments in Section 4.5.

4.2 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:

$$\Pi_{it} = p_t Z_{it}^{\beta_1} C_{it}^{\beta_2} L_i^{\beta_3} - w(1+\tau_i) C_{it} - (1-s_i) E_{it} \; . \tag{3}$$

(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 4.1. 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_1	labor	1
	F	fixed factor	1
	w	price of purchased inputs	.01
Policy Variables	τ_1	tax on purchased inputs	0 or .2
	s_1	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	$\beta_1, \beta_2, \beta_3$	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

$$Z_{i,t+1} - Z_{i,t} = \alpha Z_{i,t}(K_0 - C_{it} + E_{it}^{\varphi} - Z_{i,t}) \ . \tag{4}$$

The steady state stock level in the absence of human intervention is K_0. The steady state as a function C and E is $K_0 - C + E^{\varphi}$. 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 4.4. 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

$$\mathcal{L}_{it} = \pi_{it} + \lambda_i[\alpha Z_{i,t}(K_0 - C_i + E_i^{\varphi} - Z_{i,t}) + Z_{i,t}] \tag{5}$$

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.[13] 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}:

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

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

$$E_{it} = \left[\frac{\lambda_i \alpha \phi Z_{i,t}}{1-s_i}\right]^{\frac{1}{1-\phi}} \tag{7}$$

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

$$y_{it}=Z_{i,t}{}^{\beta_1} p_t{}^{\frac{\beta_2}{1-\beta_2}} \left[\frac{\beta_2 Z_{i,t}{}^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{\beta_2}{1-\beta_2}} \tag{8}$$

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.

$$q=AF^{\gamma}(y_1+y_2)^{1-\gamma} \tag{9}$$

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.[14] They take Q, the price they receive for the final product, as given, and their value of marginal product is $Q\partial q/\partial y_i$. We model their market power using the equilibrium condition:

$$\frac{\bar{Q}\frac{\partial q}{\partial y} - \bar{p}}{\bar{p}} = M_c \tag{10}$$

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

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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:

$$\bar{Q}^{\left(\frac{1-\beta_1}{1-\beta_2+\gamma\beta_2}\right)} H = \bar{p} \tag{11}$$

which uses the definition

$$H = \left[\frac{AF^{\gamma}(1-\gamma)(1+\tau_p)^{\frac{\gamma\beta_2}{1-\beta_2}}}{\left[1.1\sum_{i=1,2}\left[Z_i^{\beta_1}\left[\beta_2\frac{Z_i^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_i}\right]^{\frac{\beta_2}{1-\beta_2}}\right]\right]^{\gamma}}\right]^{\frac{1-\beta_1}{1-\beta_2+\gamma\beta_2}} \tag{12}$$

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:

$$f = \bar{Q}\left(\frac{\partial q}{\partial F}\right)\bigg|_{r\ fixed} \tag{13}$$

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

$$(1+\tau_c)\,\bar{Q} = Kq^{-\eta}\,. \tag{14}$$

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

$$(1+\tau_c)\,\bar{Q} = I\bar{p}^{\left(-\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}\right)} \tag{15}$$

which uses the definition

$$I = \frac{K(1+\tau_p)^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}{A^{\eta}F^{\eta\gamma}(1+\tau_c)\sum_{i=1,2}\left[Z_i^{\beta_1}\left[\frac{\beta_2 Z_i^{\beta_1}}{(1+\tau_i)w+\alpha\lambda_i Z_i}\right]^{\frac{\beta_2}{1-\beta_2}}\right]^{\eta(1-\gamma)}} \,. \tag{16}$$

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

$$\bar{Q}^{*}=\left[\frac{I}{H^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}\right]^{\frac{1-\beta_2+\gamma\beta_2}{1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma)}} \tag{17}$$

and

$$\bar{p}^{*}=H\left[\frac{I}{H^{\frac{\beta_2\eta(1-\gamma)}{1-\beta_2}}}\right]^{\frac{1-\beta_2}{1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma)}} \tag{18}$$

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

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

$$E_i^{*}=\left[\frac{\lambda_i\alpha\phi Z_{i,t}}{1-s_i}\right]^{\frac{1}{1-\phi}} \tag{20}$$

$$y_i^{*}=Z_{i,t}^{\beta_1}\left[I^{1-\beta_2}H^{1-\beta_2+\gamma\beta_2}\right]^{\frac{\beta_2}{(1-\beta_2)(1-\beta_2+\gamma\beta_2+\beta_2\eta(1-\gamma))}}\left[\frac{\beta_2 Z_i^{\beta_1}}{(1+\tau_1)w+\alpha\lambda_i Z_{i,t}}\right]^{\frac{\beta_2}{1-\beta_2}} \tag{21}$$

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 4.2.

Table 4.2. 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 3, 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[15], and consumer surplus[16], with a horizon of T years, are

$$NPV\ \pi_i^* = \sum_{t=0}^{T} \left(\frac{1}{1+\rho}\right)^t \pi_{i,t}^* \tag{22}$$

$$NPV\ Rent = \sum_{t=0}^{T} \left(\frac{1}{1+\rho}\right)^t Q \frac{-\partial q_t}{\partial F} \Big|_{F=1} \tag{23}$$

$$NPV\ Consumer\ Surplus = \sum_{t=0}^{T} \left(\frac{1}{1+\rho}\right)^t \int_{Q_t^*}^{Choke} \frac{1}{Q^{-\eta}} dQ \tag{24}$$

4.3 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

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

[16] 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.

illustrative of possible outcomes.

For the results we report, we varied λ_1, between 0 and .02, holding $\lambda_1 = \lambda_2$. For the base run we varied only λ_1, 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_1. 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 4.1 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, $K_0 = 8$, 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 4.2) of raw material decreases over time because of decreasing environmental stock.[17] The supply path for $\lambda = 0$ crosses the paths for $\lambda > 0$. For given Z, the absence of property rights ($\lambda_1 = 0$), 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 $\lambda=0$ 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 4.3 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

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[17] 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.

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.

Table 4.3. 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 4.4 through 4.6 and Figures 4.3 and 4.4 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 4.4); both countries impose the tax (Table 4.5); the North imposes a 20% tariff (Table 4.6). 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 4.3 and 4.4, 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 4.5 and 4.6).

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[18]). When property rights in the South are strong, so that the externality is not important, the tariff harms Northern consumers.

[18] 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 4.4. Unilateral Tax Policy in South: $\tau_1 = .2$, $\tau_2 = 0$

Property Rights (λ_1)	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 4.5. Multilateral Tax Policy in South: $\tau_1 = \tau_2 = .2$

Property Rights (λ_1)	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 4.6: Trade Policy Intervention from North: $\tau_p = .2$

Property Rights (λ_1)	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 4.3-4.5 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[19] 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.

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

[19] 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.

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.

4.4 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

$$y_t = f(z_t, x_{1t}, \epsilon_{1t}; \beta_1) \ . \tag{25}$$

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

$$z_{t+1} - z_t = g(z_t, x_{2t}, \epsilon_{2t}; \beta_2) \ . \tag{26}$$

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 $\{x_{21}, x_{22}, \ldots x_{2,t-1}\}$. Substituting the result into (23) gives y as a function of z_o, $\{x_{21}, x_{22}, \ldots x_{2,t-1}\}$, 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.

4.5 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 principle, 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 2, 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 explored. 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.

References

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5. 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.[20] Third, we used a standard international trade model to estimate the effects on prices, production, and trade flows of several internalization policies. Fourth, we analysed 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 behaviour is determined largely by price signals. In poorer countries, income constraints loom larger. There, to use only price policies, in the absence of transfers, might result in continued impoverishment of the world's most vulnerable peoples, 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 principle 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 policy-makers from more promising remedies.

Choosing efficient internalization charges requires knowing the marginal environmental damage associated with an activity. Our

[20]Karp, Larry with Chris Dumas, Bonwoo Koo and Sandeep Sacheti, "Review of environmental damage estimates in agriculture and internalization measures", UNCTAD/COM/54.

review of damage estimates 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 exceeds 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. In general, they 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 towards 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 analysed 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 more likely to occur as the two fields draw closer together.