The dynamic effects of trade liberalization and environmental policy harmonization

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Abstract

We study a general equilibrium model in which trade is driven by institutional differences (differences in environmental distortions) and differing factor endowments (differences in production-related environmental stocks). The endogenous evolution of environmental stocks depends on the trade regime and on the extent of environmental distortions in the two countries. The economy can have multiple steady states that depend on the policy regime and the initial stock levels. We investigate the effects of harmonization of the distortions and of trade liberalization, in the short and the long-run. The model illustrates the ambiguous effects of these reforms, and it explains why the predictions of environmentalists or economists are more likely to be born out, depending upon whether the environment is fragile or resilient.

Key words: trade versus the environment; policy harmonization; multiple equilibria.

JEL: F10, Q20

1 Introduction

Mainstream economists and environmentalists frequently find themselves on opposite sides of the "trade versus environment" debate. Economists tend to support liberal trade for reasons having little do with the environment. Environmentalists often oppose trade liberalization because they think that it is likely to harm the natural environment. Economists argue that in the long run, trade will help the environment as income rises, promoting stricter environmental regulation; as environmentally friendly technologies are diffused; or as imports of resource-intensive goods relieve environmental pressures in resource-scarce countries. Environmentalists worry that even if nations gain from trade in the short run, they may suffer as trade eventually exhausts the natural environment in the resource exporting country. Economists are skeptical of efforts to harmonize environmental regulations across nations at different stages of development. Many environmentalists think that this kind of harmonization becomes more essential with liberalized trade.

The exchange between Daly (1993) and Bhagwati (1993) exemplifies the debate between environmentalists and economists in academic circles. The disagreement over whether to grant US presidents fast-track negotiating authority for trade agreements reflects a wider debate over the merits of more liberal trade. The riots surrounding recent WTO and IMF meetings show the intensity of opposition, in some circles, to increased globalization in general, and to more liberal trading rules in particular.

The differences in opinion between the two groups might be explained by differences in values: perhaps economists and environmentalists have different assessments of the relative importance of economic growth and of the natural environment. However, the widening difference between the two groups may also be due to the polarization that occurs when each side attempts to present its case using sound-bites. The resulting debate becomes a

repetition of "talking points" that only makes each side appear more entrenched.

This chapter incorporates environmental concerns in a framework for analyzing the effects of trade liberalization and policy harmonization. Economists know that these kinds of policy changes may have ambiguous welfare effects. Many non-economists think that economic models are vacuous because the models' conclusions are predetermined in a trivial and biased manner. We show that a simple model can support contradictory positions, depending in a sensible manner on parameter values in the model. Thus, the arguments of different camps can be viewed as the expressions of different assumptions about these parameter values, rather than as world-views that are radically different and mutually exclusive. For example, our model predicts different outcomes depending on whether the environment is "fragile" or "resilient", on whether institutional differences between trading partners are large or small, and on whether we consider the short or the long run.

The underlying arguments in favor of free trade and opposed to mandatory harmonization are familiar, but worth mentioning. By enabling countries to exercise their comparative advantage, trade makes it possible to produce more goods with the same amount of resources, increasing wealth. Trade may also create dynamic benefits by encouraging the spread of new technologies; by enlarging markets, trade can lead to the exploitation of economies of scale, again increasing wealth; increased wealth might promote policies that protect the environment. Cross country differences in environmental policies might reflect differences in income, tastes, capital stocks, resource endowments, or a variety of other factors that contribute to inter-industry trade. In this case, the mandatory harmonization of environmental policies thwarts the efficient workings of the market and lowers welfare.

These arguments assume that markets work efficiently, and therefore that the goal of policy reform should be to reduce market frictions such as trade restrictions. Mainstream

economic theory recognizes that in the presence of multiple market imperfections, trade liberalization or some other market reform can either increase or lower welfare. This ambiguity, which is known as the "Theory of the Second Best", plays a central role in (academic) economic policy analysis, but is often swept under the carpet when presenting the economic arguments for trade liberalization or against mandatory environmental harmonization. For purposes of analyzing trade reform, economists sometimes assume that non-trade distortions are of secondary importance, or are not closely related to trade.

Environmentalists tend to think that other market imperfections are of primary importance, and that these imperfections are closely related to trade. We adopt this view in our model. In particular, we assume that many standard reasons for trade, such as tastes, technology, non-environmental endowments, and other characteristics are the same in the two countries. The countries differ only in their endowment of the natural resource, and in the degree of market imperfections. These two differences are the only reasons for trade.

Market imperfections arise for many reasons. We examine the situation where an institutional failure causes excessive exploitation of an environmental resource. For example, there may be imperfect property rights to the environmental resource. Whatever the exact cause of the market failure, society attempts – with limited success – to reduce the resulting economic distortion. For example, it might tax the use of the resource or impose quantitative restrictions. We assume that society is not able to perfectly correct the distortion. Hereafter, we consider the market failure to be imperfect property rights. Strengthening these property rights leads to a reduction in the socially excessive level of exploitation of the environmental resource. We use "environmental reform", or merely "reform" to describe an institutional or policy change that would lead to a smaller exploitation of natural resources if other variables (such as prices) were held constant. Harmonization means that

the magnitudes of the distortions in the two countries are made more similar.

Within our model, the short-run effects of trade and harmonization, i.e., the instantaneous effects given the environmental stocks, are standard. For example, the difference in the endowment of the natural resource is a standard source of gains from trade. To the extent that this difference is significant, trade liberalization improves economic efficiency and welfare. The difference in property rights (or some other environmental market failure) is an institutional reason for trade. When this difference is important, relative to the difference in the resource endowment, trade liberalization or the harmonization of policies have ambiguous effects.

The long-run and the short-run effects can be significantly different. The long-run effects arise from changes in the steady states as the environmental stocks change endogenously. The manner in which the stock changes depends on the trade regime (autarky or free trade), and on the levels of the environmentally-related market failure. It is possible that both countries gain from trade or harmonization in the long run, even when they lose in the short run. The critical insight is that, depending on the environmental resilience, trade can either enable a resource rich country to "pull up" a resource poor country (so both resources are preserved), or cause the latter to "drag down" the former (so that both resources are depleted).

We emphasize the long-run effects and the role of environmental resilience in determining these effects. This focus is motivated by the concern of many environmentalists about the possible depletion of the environmental resource. Different resources have different regenerating capabilities, so environmental resilience naturally plays a significant role in our long-run analysis.

A number of papers, including Chichilnisky (1993, 1994), Brander and Taylor (1997a,

1997b, 1998), and Copeland and Taylor (1994, 1995) study market failures and the relationship between trade and the environment. Our approach is different in that we emphasize the possibility of multiple steady states, which enables us to investigate qualitatively different effects of policy changes. For example, autarkic and free trade economies may reach different kinds of steady states, depending on the environmental distortions, resilience, and the starting stock levels; environmental reform can lead to qualitatively different effects in the short and the long run, and under free trade and autarky. The model that we describe in Sections 4-7 follows the analysis in Karp, Sacheti and Zhao (2001) and Karp, Zhao and Sacheti (forthcoming). Those two papers contain all of the technical details that we omit here.

Section 2 presents some of the empirical evidence on the role of market failures in the trade-versus-environment question. Section 3 discusses some foundations of economic theory that are important in order to avoid misinterpretation of our analysis. Section 4 sketches the basic ideas of our model in a fairly general setting. Section 5 outlines a particular model and describes the equilibrium at a point in time. Section 6 describes the welfare effects, at a point in time (for given levels of the environmental stocks), of a change in the trade regime or a change in environmental policy. Section 7 considers the long run effects (as the environmental stocks have time to adjust) of these kinds of changes. We conclude in Section 8.

2 Empirical Review

There is a growing body of empirical literature on the relationship between trade and the environment. Although no consensus has been reached regarding this relationship, there

is compelling evidence that overall trade may improve the environment through raising the income of the trading countries (Antweiler, Copeland and Taylor (2001)). Economists have conjectured that when countries have different degrees of environmental regulation, those with loose regulation may export more pollution intensive goods and even attract polluting industries (the pollution heaven hypothesis). However, the empirical evidence on this conjecture is far from clear. Econometric studies find little evidence of a relation between aggregate trade flows and differing levels of environmental protection, although Mani and Wheeler (1998) present evidence that trade may create transitory pollution havens.

There is some anecdotal evidence, mostly at a commodity-specific level, indicating that differing levels of market failure do influence trade flows. For example, in response to serious deforestation, China restricted logging in 12 provinces in 1998, and in 18 provinces in the year 2000. This logging ban, together with continued economic growth and a reduction in tariffs, has caused China to become one of the world's largest importers of logs. Burma, where logging is controlled by warlords, and where the environmental market failure is probably more severe than in pre-reform China, has become a primary source of supply. The environmentally beneficial policy in China could worsen the regional environmental problems by increasing the pressure on Burmese resources (Pomfret, 2001).

The empirical literature has also failed to identify the *dynamics* of the trade pattern in response to changes in the resource and environmental bases of the trading countries. A resource-rich country may exhaust its resource if it keeps exporting the resource-intensive good. This possibility is a major concern of anti-trade environmentalists who fear that even if the country may benefit from trade in the short run, it may lose in the long run as the stock is driven down. Again, there is only anecdotal evidence supporting this conjecture. For example, Thailand and the Philippines were major timber exporters in the 1970's and

early 1980's. However, they eventually exhausted many of their forest stocks and became net importers of roundwood (FAO 1994). Trade and loosely-defined property rights contributed to the exhaustion (McDowell 1989).

One of our major conclusion is that the long-run effects of trade on the environment and welfare depend in large part on the resilience of the resource stock, i.e. on how fast the resource can regenerate. In our model, trade is likely to have positive (negative) long-run effects when the resource is relatively resilient (fragile). There is no empirical investigation in the literature on how the relationship between trade and the environment depends on the nature of the environment. To the extent that trade leads to expanded economic activity and increased resource extraction in the resource exporting country, studies on the time path of economic growth in resource based economies offer indirect evidence. Diamond (1999) compares the effects of technological advance and population growth in the Fertile Crescent (the Near East) and other Eurasian regions, over a period of thousands of years. Both regions experienced rapid growth with the advent of agriculture, but the Fertile Crescent "had the misfortune to arise in an ecologically fragile environment," due possibly to low rainfall (page 411, Diamond (1999)). Eventually agriculture destroyed the resource base, leading to devastating desertification and salinization. On the other hand, Europe and China had adequate rainfall and a resilient resource base. The development of agriculture and the subsequent economic growth spurred further growth, which continues today. Brander and Taylor (1998b) documents the rise and fall of Easter Island, again due to its fragile resource base.

3 Three Ideas From Economic Theory

In order to assess the model and the results described in following sections, the reader should understand three important ideas from economic theory, discussed in this section. The Principle of Comparative Advantage helps in understanding why trade tends to increase welfare; the Theory of the Second Best shows why there may be circumstances where trade lowers welfare; and the Principle of Targeting explains why economists generally favor liberal trade even in a "second best" environment.

In many respects, the model in this chapter is standard: trade allows countries to exercise their comparative advantage, leading to possible efficiency gains. However, the existence of an environmentally-related distortion can cause trade to lower welfare. The reader might leave with the message that the theory implies only that "anything can happen" – not a particularly helpful insight, and not one that promotes the adoption of liberal trading rules. The fact that liberalized trade or environmental reform can lead to a wide range of possible outcomes does not imply that there is a theoretical argument for discouraging either trade or environmental reform. The purpose of our model is to improve our intuition about the likely effects of trade and different types of reform in different settings, and in particular to investigate differences in the short and long run and to emphasize the role of environmental resilience. Given the assumptions that we need to make in order to study these issues, our model does not provide a basis for policy recommendations. In this section we hope to give the non-economist a sufficient grounding in economic theory to avoid leaving with the wrong message.

The theoretical argument in favor of liberal trade is based on ideas concerning the efficiency of market outcomes, and on the Principle of Comparative Advantage. This Principle implies that under free trade and given that domestic markets are not distorted, a country

exports commodities that it can produce relatively more cheaply than its partners. "More cheaply" is understood in terms of "opportunity costs" rather than in terms of dollars or labor hours. It is convenient to explain the meaning of opportunity cost using a two-commodity example, since our model below involves only two commodities.

Suppose that food and steel are the only two commodities. In this setting, the opportunity cost of steel is simply the number of units of food that the economy must sacrifice in order to obtain one more unit of steel. The economy converts food into steel by reallocating factors of production from the food to the steel sector. Firms that use the factors of production, and workers and land-owners who supply these factors, maximize their profits, utility, or rent. In an undistorted competitive equilibrium, it is not possible to increase output of one commodity without decreasing output of the other commodity: the allocation of factors is efficient. The opportunity cost of steel equals the equilibrium relative price of steel, $\frac{p^s}{p^f}$ where p^s is the nominal price of steel and p^f is the nominal price of food.

If two economies have different equilibrium relative prices in autarky, then one economy necessarily has a lower equilibrium relative price of steel. That economy has a lower opportunity cost of steel – a comparative advantage in steel – and it exports steel in a free trade equilibrium. When the equilibrium trade price differs from the autarkic prices, trade increases total income in both of the countries. The income of owners of any particular factor of production might fall as a consequence of trade, but the magnitude of this fall is less than the gain in income of owners of other factors of production, so national income increases.

This conclusion depends on the assumption that the economies are "undistorted". Anything that causes the economy to be at an inefficient equilibrium can be viewed as a distortion, including imperfect competition, missing markets (e.g. absence of insurance markets)

or government policies that restrict trade (e.g. tariffs). The Theory of the Second Best states that if there are two or more market imperfections (distortions), correcting one of them may either increase or decrease welfare. For example, if there are two tariffs, eliminating one may not increase welfare. A pessimistic interpretation of this conclusion is that it implies that economic theory allows us to reach no conclusion about real world markets, since we know that these are subject to many imperfections. A more moderate interpretation is that we cannot uncritically use economic theory to conclude that a particular reform, such as trade liberalization, necessarily improves efficiency.

We provide a simple example of the theory of the second best and then discuss its application to our setting. Imagine an economy in which there are only two market failures, both of which are present in a particular sector. The first failure is that production of the commodity damages the environment, but the producer does not pay for this damage (i.e. there is a negative environmental externality). The second failure is that the industry is oligopolistic rather than competitive. These two market imperfections cut in opposite directions. The first causes the market outcome to result in excessive production, from the standpoint of society. The second causes the market outcome to result in too little production, since oligopolists (typically) sell at a point where price is greater than marginal cost. At this level of generality, we do not know whether there is too little or too much production on balance. We cannot conclude that welfare would be higher if we remove one of the imperfections, e.g., by forcing the oligopolists to produce where price equals marginal cost in order to mimic the competitive outcome. The salient feature of this example is that each distortion affects the welfare cost of the other distortion.

Our model allows for trade restrictions and an environmental distortion in each country. The Theory of the Second Best implies that a reduction in one of these distortions, such as the

elimination of the trade restriction and the switch from autarky to free trade, might increase or lower welfare. Similarly, under free trade, environmental reform in one country leads to changes in commodity prices that can affect the economic demands on the environment in the other country. Since there are two distortions under free trade – the imperfect property rights in each country – reform in a particular country might improve or worsen welfare, either at the national or global level. These possibilities arise in our model. However, our objective is not to illustrate the Theory of the Second Best, but to understand why short- and long-run effects may differ.

The Theory of the Second Best may appear to undercut economic arguments for liberal trade or for improving property rights to environmental goods. Policy decisions in the real world always involve many distortions that policy-makers reasonably regard as fixed. A set of theoretical results known as the Principle of Targeting (Bhagwati, Panagariya and Srinivasan (1998)) explain why economists remain broadly united in favor of liberal trade and strong property rights. This Principle merely states that distortions, or market failures, should be "targeted" as directly as possible.

For example, suppose that policy-makers believe that domestic agricultural production provides security that benefits society. Consumers do not pay for, nor are producers compensated for, this security. The competitive equilibrium results in too little domestic production, from the standpoint of society, because producers do not take the social benefit of improved security into account when making their production decisions. In this situation, an agricultural import tariff (or export subsidy) improves the competitive equilibrium. Such a tariff or subsidy is a second-best policy: it ameliorates the distortion caused by producers' failure to internalize the positive production externality, but in the process it creates a consumption distortion. On balance, the second-best tariff improves welfare, but it does so at a cost.

The first-best policy in this example is an agricultural production subsidy. The "target", after all, involves the level of production. A production subsidy achieves this target without generating other distortions.

In our model, the underlying market failure is an environmental distortion. The Principle of Targeting implies that the optimal policy should address this distortion directly. When environmental policy fails to eliminate the market distortion – as we assume – trade restrictions can lead to net welfare gains, but they do so by introducing other distortions.

Our model has only two types of departure from an efficient equilibrium, the environmental distortions and trade restrictions. We study only trade liberalization and a particular kind of environmental reform. Consequently, our analysis does not provide a basis for policy recommendations – and certainly it does not support an anti-trade or anti-property rights agenda.

4 A General Model

The long-run effects of trade and environmental reform depend on the steady state that the economies reach. In our model, economies may have multiple steady states, and these may differ qualitatively. Here we provide a graphical analysis that illustrates why there might be multiple steady states under both autarky and free trade, and the differences between the steady states. Moving from autarky to free trade can lead to qualitatively different steady states, and the effect of environmental reform can be qualitatively different under autarky and free trade.

In our model, the environmental problem is national rather than global. Production decisions within a country directly influence the environment only in that country. Thus,

under autarky, decisions within a country have no affect on the other country. International trade links the markets in the two countries. With trade, production decisions within a country affect world prices, and these affect production decisions and the environment in other countries. Trade causes national environmental problems to become multi-national problems.

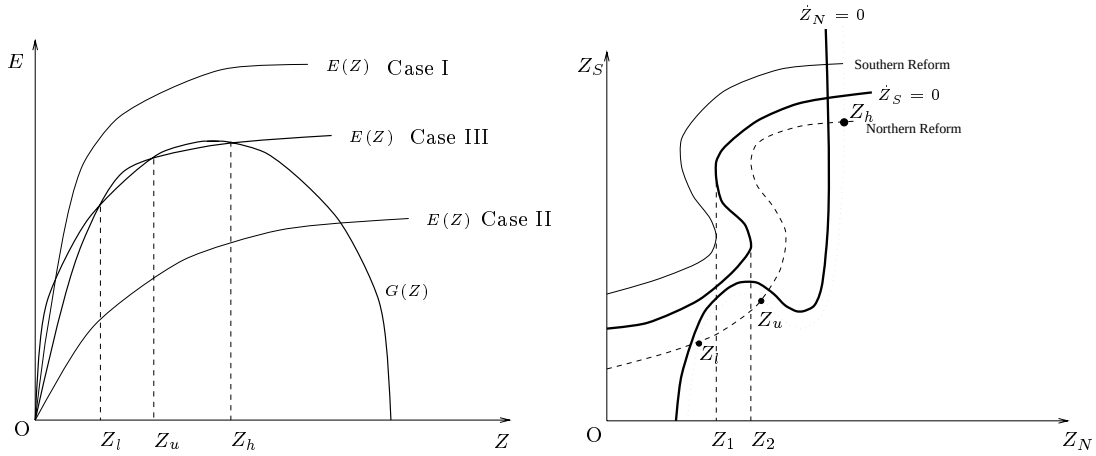
In the next three subsections, we explain why there may be multiple steady states under both trade and autarky. We show how trade can change the steady state that an economy approaches; then we explain how environmental reform can change the equilibrium when we hold the trade regime fixed.

4.1 The Existence of Multiple Steady States

Suppose that the production of final goods requires environmental services (E), the supply of which is endogenous. The cost of producing E (a flow variable) decreases with the environmental stock Z. The E-producing industry has a market failure that leads to an inefficiently high exploitation of the environmental stock and an inefficiently high supply of environmental services, for a given stock level. The magnitude of this distortion is measured by δ; a larger value of δ implies a greater market failure.

The equilibrium supply of E depends on both the market failure and the current environmental stock Z: $E = E(Z, \delta)$. A larger environmental stock decreases the cost of supplying environmental services but at a decreasing rate, so that $E_Z \geq 0$ and $E_{ZZ} \leq 0$. A larger market failure increases the equilibrium supply of environmental services for a given stock: $E_\delta \geq 0$. Environmental reform means that the distortion is reduced, i.e. δ is reduced.

In order to obtain a specific functional form for $E(Z, \delta)$ we need to specify the market failure and the nature of the producer's optimization problem (among many other things).



(a) Autarky (b) Trade

Figure 1: Possibilities of Steady States

At this stage, we do not need that degree of detail. The intuition for our results depends on the curvature of the extraction function, described above.

To complete the description of the model we assume that the natural growth rate of the environmental stock (absent extraction) is a strictly concave function $G(Z)$ that increases for small Z, reaches a maximum, and then decreases to zero (at the natural carrying capacity). The steady state of the autarkic economy depends on the relation between $G(Z)$ and $E(Z, \delta)$. Figure 1a illustrates three possible configurations. In Case I, there is a unique low steady state and in Case II, there is a unique high steady state. Case III shows a situation where $G(Z)$ and $E(Z, \delta)$ intersect at three points, a low steady state, Z_l, a high steady state, Z_h and an intermediate (unstable) steady state, Z_u. The economy moves toward either the high or the low steady state, depending on whether the initial level of Z is above or below Z_u.

In a trade equilibrium, two countries, North and South, exchange commodities that use environmental services as inputs. At a point in time, their environmental stocks are Z_N and Z_S. As was the case under autarky, E_i (the equilibrium supply of environmental services in

country i) depends on Z_i via its direct effect on production costs, and on the market failure, δ_i; E_i also depends on the price of environmental services, which depends on the aggregate (world) supply of services. With trade, the supply of environmental services in country i (E_i) therefore depends on the environmental stocks and the market failures in both countries. An increase in Z_N, for example, decreases North's relative costs of producing environmental services. Under plausible circumstances, higher Z_N increases the equilibrium supply of E_N and decreases the equilibrium supply of E_S.

Figure 1b shows the relation between the two countries' steady states. The heavy line labeled $\dot{Z}_S = 0$ shows the set of stocks in $Z_N - Z_S$ space at which South's stocks are in long-run equilibrium. This curve can be non-monotonic, as shown. For $Z_N < Z_1$ (i.e. for low levels of Z_N), South produces environmental services not only for domestic use, but also for export (embodied in final products). Thus, under trade, a low level of Z_N implies that the steady state for Z_S is also low. (This situation corresponds to the case where the graph of E_S as a function of Z_S is high, as in Case I in Figure 1a; there $\dot{Z}_S = 0$ has a unique solution at a low steady state.) Increases in Z_N shift the supply of environmental services from South to North, and therefore shift down the graph of E_S (as a function of Z_S). This change increases South's low steady state. When North's environmental stocks are high ($Z_N > Z_2$), North provides the bulk of environmental services and South's extraction is low. Here, Case II in Figure 1a applies; there is a unique solution to $\dot{Z}_S = 0$, the high steady state. Again, increases in Z_N raise this steady state. For intermediate levels $Z_1 < Z_N < Z_2$, Case III in Figure 1a applies; there are two stable and one unstable solutions to $\dot{Z}_S = 0$. Over this region, an increase in Z_N increases both of South's stable steady states and decreases the unstable steady state.

The curve labeled $\dot{Z}_N = 0$ shows the set of steady states for North, as a function of

South's stock. Figure 1b illustrates the case where there is a unique high steady state for both countries under trade: the heavy solid curves intersect at a single point, involving high stocks in both countries. There are, however, several other possibilities. For example, the graphs might intersect more than once (giving rise to multiple steady states) or they might intersect only at low steady states.

4.2 The Effects of Trade on the Steady States

Figure 1b indicates the possibilities that both countries reach high or low steady states under trade. Although at this level of generality it is impossible to precisely link the autarky and trade steady states, it is conceivable that under autarky the two countries may reach different steady states due to their differences in either the initial stock levels or the environmental distortions. For example, it is possible that North is described by Case II while South is described by Case I in Figure 1a. Then trade may cause a *qualitative* change in the steady state for at least one country: If under trade the relevant $\dot{Z}_N = 0$ and $\dot{Z}_S = 0$ curves are the bold lines in Figure 1b, both countries reach high steady states and trade increases long-run aggregate welfare. But if both countries reach the low steady states, trade might reduce long-run aggregate welfare.

The particular process through which the two countries move to the high or low steady states can only be studied using a more specific model. Here we outline two possibilities. Suppose that under autarky North is described by Case II (a unique high steady state) and South is described by Case I (a unique low steady state) in Figure 1a, and that the two countries start at similar stock levels. South has higher extraction due to its worse environmental distortion, making it likely that South exports the environmentally intensive good. Trade initially further depletes South's stocks and leads to an increase in North's

stocks. Eventually, comparative advantage in the environmentally intensive good shifts from South to North. This change can enable South's stocks to recover, and eventually both countries can reach the high steady states. In this case, North "pulls up" the South under trade. Another possibility is that the higher North extraction eventually depletes the North's stock without enabling South's stock's to recover. In this case, both countries approach the low steady states: trade causes South to "drag down" North. The actual outcome depends in part on how quickly Southern stock can recover, i.e. on the resource's resilience. The "pull up" scenario is more likely when the resource is more resilient.

This example merely shows that, in the presence of multiple distortions (environmental distortions in both countries and trade restrictions), the elimination of one distortion (here, the trade restriction) can lower welfare. The example illustrates the Theory of the Second Best. At this level of generality we can only conclude that the effects of trade are ambiguous. In order to understand how the economic and environmental fundamentals are likely to determine these effects, we need a less general model.

4.3 The Effects of Environmental Reform on the Steady States

We first consider the case of autarky in Figure 1a. Reform corresponds to a decrease in δ, leading to a downward shift in the curve $E(Z, \delta)$. The market failure means that the environmental sector absorbs more inputs than is socially optimal. Reform reduces the market failure and decreases the inputs used in extraction, increasing welfare in the short run.

The long-run welfare effects of the reform depend on the change in the steady states. A large reform (a sufficiently large downward shift in $E(Z, \delta)$) can eliminate the low steady state, leaving the high steady state as the unique long run equilibrium (Case II). When this

happens, reform can lead to a qualitative change in the steady state, and a correspondingly large welfare change.

With trade (Figure 1b), environmental reform in one country, say North, increases its costs of producing the environment-intensive good. This reform decreases North's equilibrium extraction level and increases extraction in South. At the initial relative prices, a reduction in North's environmental distortion leads to a more efficient allocation of resources in North and a rise in its welfare. The decrease in North's supply of environmental services increases the price of the commodity that uses these services relatively intensively. If North is an importer of the environmentally intensive good, reform causes its terms of trade to deteriorate. The net short-run welfare impact for North depends on the relative magnitudes of the direct effect and the price effect. At the initial relative prices, North's reform increases the relative severity of the distortion in South. By making South's allocation of resources less efficient, this reform tends to lower South's welfare. However, if South exports the environmentally intensive good, North's reform improves South's terms of trade. Again, the net short-run welfare effect depends on the relative magnitudes of the direct effect and the price effect.

To study the long-run effects of reform, we again consider the changes in the steady states as one or both countries reform. For any level of Z_N, reform in South increases its stable steady states. The mechanism is the same as under autarky. Southern reform therefore shifts the $\dot{Z}_S = 0$ isocline up to the left (the thin solid curve in Figure 1b). Reform in North shifts production of environmental services to South, lowering South's stable steady states. North's reform shifts the $\dot{Z}_S = 0$ isocline down to the right (the dashed curve in Figure 1b). (These two reforms have similar effects on the curve labeled $\dot{Z}_N = 0$. We do not show these effects in order to avoid cluttering the graph.)

Suppose North reduces its environmental distortion. This reform shifts the $\dot{Z}_N = 0$ curve to the right, to the dotted curve. In addition, as explained above, North's reform shifts down the $\dot{Z}_S = 0$ curve. Figure 1b illustrates a situation in which North's reform leads to two stable (and one unstable) steady states. (The two post-reform dotted curves intersect at three points.) If the initial condition is such that the equilibrium moves toward the low steady state, North's reform leads to lower stocks and a likely welfare reduction in the long run in both countries. In this case, even if Northern reform improves the short-run welfare of one country, in the long run the welfare in both countries can fall because reform lowers the steady state environmental stocks.

Comparing Figures 1a and 1b also shows that the effects of reform can be much different in closed and open economies. Reform increases the steady state stock in a closed economy and thereby improves the country's welfare. In an open economy, reform might harm a country in both the short and the long runs. Again, this ambiguity arises because with trade there are two relevant distortions, the market failure in each country.

5 A Special Model

This section describes a model that is simple enough to yield a closed form solution, and yet general enough to admit the kinds of possibilities illustrated in the previous section. This model helps to identify the circumstances that make one outcome or another more likely. Here we describe the static model, explain the equilibrium, and discuss some of the special features of the model. Section 7 imbeds this model in a dynamic setting.

5.1 Description of the Model

Figure 2 shows a flow chart of the autarkic economy. The top arrow shows that the stock and flow in the previous period (Z_{-1}, E_{-1}) affect the current stock, Z. We return to this dynamic relation in Section 7, and here consider only the static aspects of the model. There are two goods: the "subsistence good" F which we choose as the numeraire (i.e., its price is normalized to 1), and the "composite good" S that has price p.

To help fix ideas, we can think of good F as food, good S as steel, Z as the stock of water in lakes, and E as the flow of water used in production. Food is a pure consumption good, and its income elasticity falls as income increases. Steel can be consumed (in the form of cars) or used for pipes to transport water from lakes to agricultural and steel production. A poor economy uses steel only for pipes, but a richer economy also consumes cars. Water in lakes is a renewable resource that provides benefits only as a factor of production. A larger stock of water means that supplies are closer to production, so less steel is needed to obtain usable water.

Food and steel are competitively produced using labor L and environmental services E with Leontief technologies:

$$F^p = \min\left\{\frac{E_F}{a_F}, \frac{L_F}{b_F}\right\}; \qquad S^p = \min\left\{\frac{E_S}{a_S}, \frac{L_S}{b_S}\right\}. \tag{1}$$

This technology implies, for example, that production of F^p units of food requires the use of at least $a_F F^p$ units of environmental services, and at least $b_F F^p$ units of labor. We assume that S is relatively environment-intensive, which means that, compared with food, it requires relatively more E to produce: $\frac{a_S}{a_F} > \frac{b_S}{b_F}$. Our results do not change if we reverse this inequality.

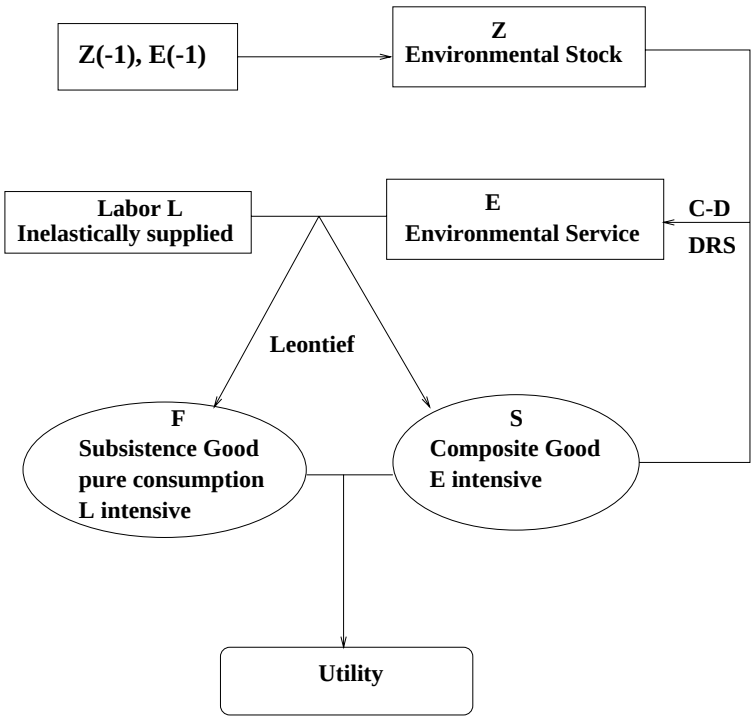


Figure 2: Structure of the Economy

The representative consumer attempts to purchase F^* units of F. If her income, y, is less than F^*, she spends everything on good F, receiving utility y (equal to the consumption of F). If her income exceeds F^*, she buys F^* units of good F and $(y - F^*)/p$ units of S, resulting in utility $F^* + (y - F^*)/p$. These preferences provide a simple way to describe a situation where the share of income spent on food falls as income rises, for income above the critical level $y = F^*$. We assume that the representative consumer's income exceeds this critical level.

The supply of labor is exogenously fixed at $\bar{L}$. Environmental services, E, are "extracted" from the environmental stock Z using S^e units of good S with a decreasing returns to scale technology. Larger stocks decrease the costs of producing E. Let p^e be the price of E. We

assume that the equilibrium supply function for environmental services is

$$E = \frac{\delta Z p^e}{p}. \tag{2}$$

This relation can be derived from the assumptions that (i) the aggregate production function for environmental services is $E = (S^e Z)^{.5}$ and (ii) n (a fixed number) producers share total output, with each producer's share proportional to his share of inputs. The non-cooperative Nash equilibrium to this game implies equation (2), with $\delta = 1 - 1/(2n)$. For $n > 1$ ($\delta > 0.5$) – as we assume – the value of marginal product of S in the extraction sector is less than the price of steel. The environmental sector absorbs too much of the input S. Production is inefficient, and the degree of inefficiency increases with δ. We refer to δZ as the *apparent stock* of this economy. A larger distortion or a larger physical stock both increase the apparent stock and therefore increase extraction.

The assumption that income exceeds F^* implies that the consumption of F is fixed at F^*. In this case, the economy's welfare is measured by the consumption of S, which equals the production of S minus the amount used in the extraction industry S^e (and the net export in the case of trade).

The two economies, North and South, are identical except for their values of δ and (possibly) their stock levels. We assume that $\delta_S > \delta_N$, so the environmental distortion is worse in South. When the countries trade we assume that both countries produce both goods, which implies that factor prices (the prices of E and L) are equal across the countries.

We use the following conventions:

Definition 1 Environmental reform *in country i means a reduction in δ_i.* Harmonization *of environmental policies means a reduction in δ_S/δ_N.* Upward harmonization *means a*

reduction in δ_S/δ_N caused by a decrease in δ_S. Downward harmonization *means a reduction in δ_S/δ_N caused by an increase in δ_N.*

Downward harmonization is consistent with a "race to the bottom", while upward harmonization is consistent with a "race to the top."

5.2 Description of the Equilibria

Our assumptions about preferences and technology imply that there is a simple relation, depending on δ, between the stock level Z and the equilibrium extraction level of E. Figure 3 graphs this relation for two levels of distortion: $\delta_1 > \delta_2$. Given δ, the equilibrium level of extraction increases with the stock, for low stock levels. When the stock exceeds a critical level – denoted $Z^c(\delta)$, a decreasing function of δ – further increases in the stock have no effect on the equilibrium extraction of E.

The reason for this result is that the fixed labor supply becomes fully employed when $Z > Z^c(\delta)$. Our assumptions about preferences and technology, together with our assumption that the economy is rich enough to produce F^*, mean that a fixed amount of labor is used in sector F. Consequently, there is a fixed amount of labor available for Sector S. Since labor and environmental services are used in fixed proportions, the demand for environmental services is also fixed when labor is fully employed. Then further increase in the stock does not raise the extraction level, although it reduces the costs of extraction.

If the stock of Z is sufficiently large ($Z \geq Z^c(\delta)$), the equilibrium supply does not vary with the stock of the resource. Thus, for $Z > Z^c(\delta)$, reform affects neither the extraction of E nor the flow of welfare in autarky. If $Z < Z^c(\delta)$, reform reduces E and raises the critical level Z^c.

Under free trade, we assume that both countries are incompletely specialized (in equi-

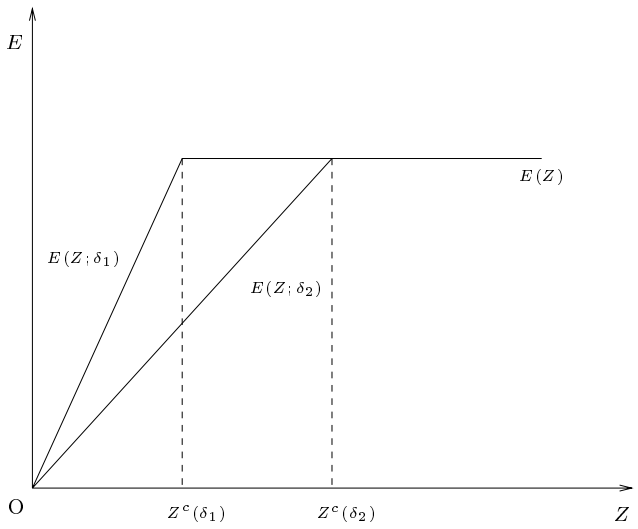


Figure 3: The Extraction Function: $\delta_1 > \delta_2$

librium), so factor prices are equal. Consequently, labor is unemployed (and its price is 0) either in both countries or in neither country. Since the equilibrium depends on stocks in the two regions, the assumption of incomplete specialization restricts our analysis to a certain region of the state space – a region where the two stocks are not extremely different. This restriction greatly reduces the number of types of static equilibria that we need to study. Unemployment (in both countries under autarky and trade) corresponds to a region where both stocks are fairly small (but still large enough to support consumption of F^*); full employment (in both countries under autarky and trade) corresponds to a region where both stocks are quite large.

When labor is unemployed, there is only one constraining factor of production, E, resulting in the standard Ricardian model. In view of the assumption that countries have the same technology, the autarkic and free trade equilibria are identical. In this case, the aggregate supply of E is the same under free trade and autarky. This supply is increasing in both δ_S and δ_N: reform in either country reduces the supply of E in that country.

If labor is fully employed, the technologies and utility function imply that the total

amount of E used in the world production of F and S is fixed. In addition, aggregate E under trade equals the sum of the autarky full employment levels of E in the two countries. However, the distribution of this aggregate level depends on the apparent stocks, and thus on the property rights. Using equation (2) and the assumption that factor prices are equal, we have $\frac{E_S}{E_N} = \frac{\delta_S Z_S}{\delta_N Z_N}$. Reform in either country affects extraction levels in both countries, but not aggregate extraction. However, reforms in both countries that leave the relative property rights δ_S/δ_N unchanged do not affect extraction in either country.

The distinction between "real" and "apparent" comparative advantage is straightforward in this model. The countries have the same technologies and preferences, i.e. they are the same except for δ and Z. The country with higher δZ has a lower autarkic price of S and therefore has an apparent comparative advantage in S (and exports S). However, the social opportunity cost of S is lower in the country that has the higher value of Z. For example, South's opportunity cost of producing the resource intensive good is lower than North's if and only if $Z_N < Z_S$, but its autarkic price of S is lower than North's if and only if $\delta_N Z_N < \delta_S Z_S$ Thus, for $Z_S < Z_N < \frac{\delta_S}{\delta_N} Z_S$, South has an "apparent" but not a "real" comparative advantage in the production of S.

5.3 Discussion of the Model

Our assumptions about preferences and technology make this model tractable. Here we discuss whether those assumptions are reasonable, and describe their important implications.

Any general equilibrium model that admits a closed form solution requires simple functions for preferences and technology. The Cobb-Douglas functional form is an obvious alternative to our choices. That function implies that consumers always spend the same fraction of their income on a particular commodity, regardless of price and income; the

elasticity of demand with respect to income is a constant, unity. In addition, a particular input always accounts for the same fraction of a firm's costs, regardless of prices and output; the elasticity of substitution is constant with the Cobb-Douglas form. In contrast, our assumptions about utility and technology imply that there is no substitutability in either consumption or production. Neither extreme assumption – zero or constant positive elasticity of substitution – is realistic. Our utility function implies that the elasticity of demand for the subsistence good falls from unity to zero as income crosses a threshold. Although this discontinuity is not plausible, the fact that the elasticity falls is reasonable.

The lack of substitutability in our model leads to a piece-wise linear extraction function, and this makes it possible to obtain some clear results when we introduce dynamics. This extraction function implies that under autarky the environmental distortion has no effect on the equilibrium when environmental stocks are large, but it has a significant effect when stocks are small. The implication that the distortion is less important to an economy when stocks are large is both reasonable and important. The discontinuity that occurs as the stock passes a threshold is not particularly plausible, but it does help to emphasize one effect of trade. When the environmental stocks in both countries are large, the distortion matters under trade, but not under autarky.

Some environmentalists are concerned that trade, by increasing aggregate world production, will increase environmental pressures. In our model, trade has no effect on aggregate production, or on the aggregate pressure on the environment when stocks are large. It does, however, affect how this aggregate environmental demand is allocated over countries. Standard trade models emphasize that in moving from autarky to trade, production is reallocated over countries. Our model shows how this reallocation leads to both short and long-run environmental consequences.

6 Short-run Effects of Trade and Reform

Here we discuss the short-run effects of a movement from autarky to trade, and the short-run effects of environmental reform under autarky and under trade. Our welfare comparisons use the utility function described in the previous section. In particular, a country's welfare increases with the consumption of commodity S; aggregate (i.e., world) welfare increases with the aggregate consumption of S.

6.1 The Effects of Trade

The short-run effect of trade on resource extraction and welfare depends on the stock levels in both countries. Figure 4 divides the (Z_N, Z_S) plane into six regions, bounded by the horizontal and vertical lines at the critical levels Z_S^c and Z_N^c and by the line labeled FEL (the full employment line).[1] FEL is defined as the set of points that satisfy $\delta_N Z_N + \delta_S Z_S = \delta_N Z_N^c + \delta_S Z_S^c$. In the free trade equilibrium, labor is fully employed if the stock levels lie above this line.

For the purpose of describing the six regions identified in figure 4, the reader should ignore the 45^o line and the line labeled NTL. For stocks in region I, labor is fully employed in both economies under both trade and autarky. In region IV labor is unemployed in both economies under both trade and autarky. In regions II or VI labor is unemployed in one economy under autarky, but fully employed in both economies under trade. In regions III and V labor is unemployed in both economies under trade, but is fully employed in one economy under autarky. We focus on Region I, but the analysis can be extended to other regions.

[1] This figure is a simplification of the full taxonomy of equilibria. It ignores the constraints needed to insure that $F \geq F^*$ and that both economies are diversified in the free trade equilibria.

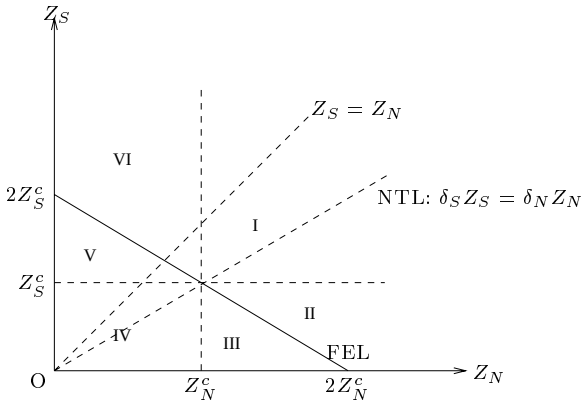


Figure 4: Possibilities of Going From Autarky to Trade

The line labeled NTL (the "No Trade Line"), defined as $\delta_N Z_N = \delta_S Z_S$, shows the stock levels at which the autarkic relative prices are equal in the two countries (i.e. the countries have the same apparent stocks). For these stock levels, no trade occurs. For stocks in Region I below this line, North has the apparent comparative advantage in, and exports, commodity S; above this line, South exports S. However, North has the real comparative advantage in commodity S if and only if stocks lie below the 45^o line ($Z_S = Z_N$). For stocks within the cone defined by NTL and the 45^o line in Figure 4, the apparent and real comparative advantages are reversed. For stocks in this cone, the "wrong" country exports commodity S, and trade lowers aggregate welfare.

Even outside this cone, trade can reduce aggregate welfare due to the inefficient volume of trade. For example, for stocks slightly above the 45^o line, the two countries are similar in their endowments. Allowing them to trade creates small welfare gains if $\delta_S = \delta_N$. But because $\delta_S > \delta_N$, trade exacerbates the negative effects of Southern distortion, as now South produces more S. The negative welfare impacts in this case exceed the positive effects. However, aggregate welfare increases under trade if the Southern stock is sufficiently high, i.e., when the stocks in Figure 4 lie far above the 45^o line. In this case, the countries are sufficiently different in their endowments that the gain from trade can overcome the loss

from exacerbating South's distortion.

Trade affects the welfare of individual countries differently. The S importing country always gains from trade. This country exercises its comparative advantage and enjoys the standard benefits of trade; in addition, its imports reduce domestic extraction of E, ameliorating the environmental distortion. For the country that exports S, trade increases extraction of E and exacerbates the environmental distortion. Welfare in the S exporting country increases if and only if the benefits of exercising its comparative advantage outweigh the costs resulting from the more serious environmental distortion (the worsened allocation of factors of production). For stocks in Region I near NTL, a country's apparent comparative advantage is negligible, but the welfare effect caused by the reallocation of demand for environmental services is significant. Thus, a sufficient condition for the S exporting country to have lower static welfare under trade is that the stock levels lie close to the NTL line.

6.2 Environmental Reform in Open and Closed Economies

We noted that under autarky, environmental reform affects the economy only when $Z < Z^c(\delta)$. In this case, reform reduces the supply of E and improves welfare. If stocks in both countries are small (e.g. in Region IV), the autarkic relative prices are equal in the two countries and they have no incentive to trade. In this case, reform has the same effects under trade as under autarky.

If stocks are large (e.g. in Region I), upward or downward harmonization (smaller $\frac{\delta_S}{\delta_N}$) improves aggregate welfare equally, while an increase in $\frac{\delta_S}{\delta_N}$ decreases aggregate welfare. Reform narrows the gap between the price of steel and the value of marginal product of steel in the reforming country's E sector, leading to an efficiency gain there. However, this reform

induces the trading partner to produce more E, and lowers efficiency there. The efficiency loss under trade arises from the *difference* in (or the ratio of) the distortions in North and South, rather than their absolute magnitudes; therefore, harmonization in either direction improves world welfare.

For example, Northern reform decreases its production of E, increases South's production of E and leaves unchanged the aggregate supply of E, F $(= 2F^*)$ and S. Since $\delta_S > \delta_N$, the value of marginal product of S (in the production of the input E) is lower in South. The price of steel is equal in the two countries under trade, so the gap between the value of marginal product of steel and the price of steel is greater in South than in North. As North reforms, the total production of E is unchanged, but production has become less efficient because more E is produced in South; the total amount of S used in the E sectors has increased. Consequently, the amount of S available for consumption has decreased, and aggregate world welfare falls. Reform in South, on the other hand, increases world welfare.

Consider now an individual country's welfare when stocks are in Region I. We already described the effect of reform in one country on the efficiency of the E sectors in both countries. Environmental reform also increases the equilibrium price of steel, the commodity that uses E relatively intensively. Therefore, reform in the steel exporting country necessarily improves its welfare and harms its trading partner. The direct effect on production efficiency and the terms of trade effect are both positive for the reforming exporter, and both are negative for the trading partner. When an importing country reforms its domestic environmental distortion, the welfare effects for both countries are ambiguous. In both countries the production efficiency effect and the terms of trade effect have the opposite signs.

Equal-proportionate reform in the two countries that leaves relative distortions unchanged does not alter E_i or aggregate welfare. However, this reform reduces world apparent

resource stocks and raises the price of food. Equal-proportionate reform thus benefits the exporter of the environmentally intensive good and harms the importer.

7 Long-Run Effects of Trade and Reform

To study the long-run effects, we assume the evolution of Z is given by the logistic growth function $\frac{dZ_i}{dt} = \dot{Z}_i = \eta Z_i - \gamma Z_i^2 - E_i$, for $i = N, S$. In keeping with our assumption that tastes and technology are the same in the two countries, we assume that this function is also the same in the two countries. The parameter γ captures the congestion effect of the stock; $\gamma > 0$ insures that Z is bounded. The non-congested growth rate of the environment, η, provides a measure of environmental resilience. When η is large, the environmental stock recovers quickly from low levels. We associate a large value of η with a resilient environment, and a small value of η with a fragile environment. The carrying capacity of the stock is $\frac{\eta}{\gamma}$ and the stock that maximizes the sustainable yield is $\frac{\eta}{2\gamma}$. The level of E_i is the amount of extraction (the flow of environmental services) at a point in time.

The dynamic equilibria for autarky and trade are sequences of the static equilibria studied in the last section. The static equilibria describe what happens under autarky and trade given the stock levels. As the countries extract E, the stock levels evolve, changing the associated autarky and trade equilibria. In a steady state, the stock levels and the associated autarky and trade equilibria remain constant. (The economies approach the steady state asymptotically, i.e. as $t \to \infty$.) In studying the long-run effects, we investigate how the steady states change as the economies move from autarky to free trade, or as they improve property rights (reduce δ).

Under both autarky and trade, there could be unique or multiple steady states, depending

on the magnitude of η relative to critical values of that parameter. Figure 5 describes the possible steady states in our special model, and is therefore a specialization of Figure 1. The figure shows two kinds of steady states: a low steady state is one that is less than $\eta/2\gamma$ (the stock level that produces the maximum sustainable yield), and a high steady state is one above $\eta/2\gamma$. Given the equilibrium extraction function $E(Z)$, which is independent of η, the economy is more likely to move to the high steady state when η is higher (i.e. as the natural growth curve rises in Figure 5(a)).

In particular, under autarky there exist two critical values of η, denoted as η^{LA} and η^{HA}, with $\eta^{LA} < \eta^{HA}$. There is a unique low steady state, Z_l, if $\eta \leq \eta^{LA}$, a unique high steady state Z_h if $\eta \geq \eta^{HA}$, and both low and high steady states (together with an unstable steady state Z_u) if $\eta^{LA} < \eta < \eta^{HA}$. (The superscripts L and H denote critical values for low and high steady states, and the superscript A denotes autarky.) Similarly, under trade, the critical values are: η^{LT} such that there is a unique low steady state $\boldsymbol{Z_l} = (Z_{Nl}, Z_{Sl})$ if $\eta \leq \eta^{LT}$; η^{HT}, such that there is a unique high steady state $\boldsymbol{Z_h} = (Z_{Nh}, Z_{Sh})$ if $\eta \geq \eta^{HT}$. If $\eta^{LT} < \eta < \eta^{HT}$ there exist both low and high steady states and an unstable steady state $\boldsymbol{Z_u} = (Z_{Nu}, Z_{Su})$. (The superscript T denotes trade.)

The value of η is determined by physical systems, and does not respond to policy changes. However, a policy change such as a move from autarky to trade, or an environmental reform that decreases δ, can change some of the critical values of η defined above. Policy reform can therefore change the relation between the fixed value of η and the endogenous critical levels of η. Such a change can cause a *qualitative* change in the steady states, i.e. it can change the types of steady state (high or low) that the economies reach.

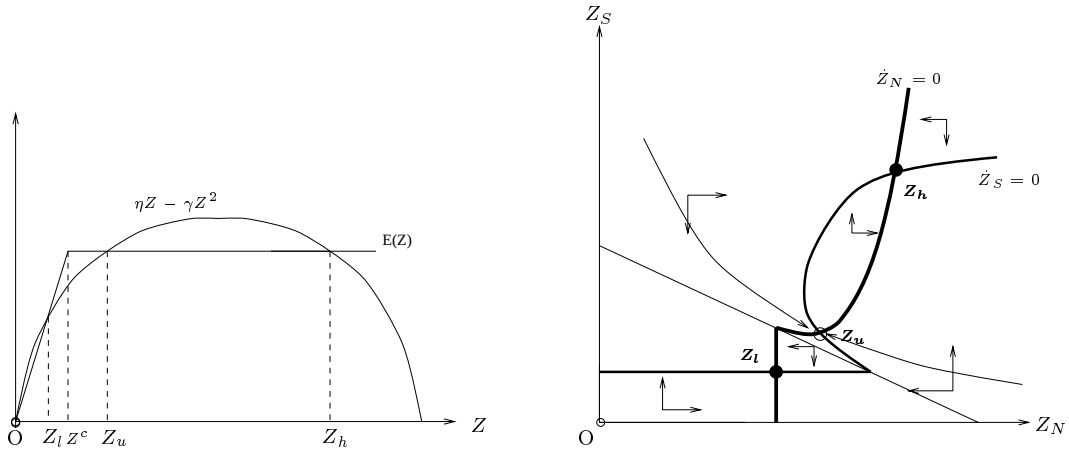
Some policy changes have different types of effects on different critical values. This fact explains why the actual value of η is important in determining the long-run effects of the

policy. This relation is essential to the rest of the analysis in this chapter. Suppose, for example, that a particular policy change increases the low critical value and decreases the high critical value of η. If the actual value of η is low (i.e. if the environment is fragile), this policy change is likely to be harmful, because it makes it "more likely" that the economy reaches a low steady state. The potentially beneficial effect of the reduction in the high critical value is irrelevant, since the actual value of η is not close to that critical value. In contrast, the increase in the low critical value is likely to be important, since the economy is close to that value. On the other hand, if the actual value of η is high (i.e., the economy is resilient), this policy change is likely to be beneficial, because it makes it "more likely" that the economy reaches a high steady state. Thus, the long-run effect of the policy change depends on whether the actual value of η, or the resilience of the environment, is close to the low or the high critical value.

Figure 5 shows examples of autarkic (panel a) and trade (panel b) equilibria. We show only examples of the situation where there are multiple steady states under autarky and free trade. Under autarky, the economy moves to Z_h if the initial stock $Z_0 > Z_u$, and it moves to Z_l if $Z_0 < Z_u$. Under trade, the economies move to $\boldsymbol{Z_h}$ if their initial stock combination is above the saddle path – the solid curve going through the unstable steady state $\boldsymbol{Z_u}$; for initial stocks below the saddle path, the economies move to the low steady state. In panel (b), the curves labeled $\dot{Z}_S = 0$ and $\dot{Z}_N = 0$ divide the plane into several regions. The arrows in the figure show the direction of motion of the stocks in each of these regions.

7.1 The Long-Run Effects of Trade

To identify the critical values for a particular country under autarky, we use subscripts, η_S^{iA} and η_N^{iA} for South and North, $i = L, H$. The critical value above which only a high steady



(a) Autarky: $\hat{\eta}^a < \eta < \eta^{*a}$ (b) Trade: $\hat{\eta} < \eta < \eta^*$

Figure 5: Resource Dynamics with Multiple Steady States

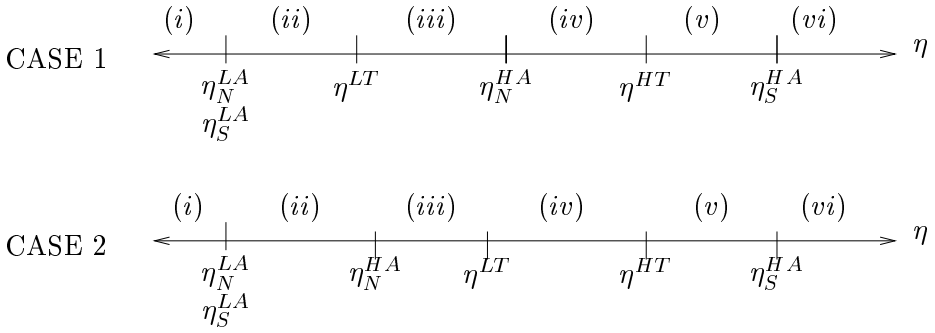


Figure 6: Possible Ranking Schemes of Critical η Values

state exists is different in North and South: $\eta_N^{HA} < \eta_S^{HA}$. North is more likely to avoid the low steady state given its less severe distortion. The autarkic critical values below which only a low steady state exists is independent of the domestic distortion. These two critical values are therefore the same for North and South: $\eta_N^{LA} = \eta_S^{LA} \equiv \eta^{LA}$. Figure 6 shows the two possible rankings of the critical values of η defined above. With both of these rankings, two important inequalities hold.

The first of these is $\eta^{LT} > \eta^{LA}$. This inequality means that there are values of η for which both autarkic economies might reach a high steady state (depending on the initial level of the stock), but under trade these two economies necessarily reach a low steady state

(regardless of initial stock levels) . If $\eta^{LT} > \eta > \eta^{LA}$ and the initial environmental stocks in both countries are high ($Z_i > Z_i^c$ for $i = N, S$), the countries would reach high steady states under autarky. When they begin to trade, Southern extraction increases, leading to a decline in its stock. Due to the low growth rate, Southern stocks are unable to recover. Eventually, North begins to extract more to compensate for low Southern extraction. In the process it drives its stocks to a low level, and both countries move to the low steady state. This circumstance illustrates the outcome environmentalists fear. Trade causes the two countries to drag each other down.

The other important inequality is $\eta_N^{HA} < \eta^{HT} < \eta_S^{HA}$. This inequality is consistent with two possibilities. First, if $\eta_N^{HA} < \eta < \eta^{HT}$, then North certainly reaches a high steady state under autarky, but it might reach a low steady state under trade. This outcome is similar to the situation described in the previous paragraph. The second, and more optimistic case is where $\eta^{HT} < \eta < \eta_S^{HA}$. In this situation, there is a unique high steady state under trade. Under autarky, South reaches a low steady state if its initial stock is low (if $Z_S < Z_S^c$). For example, suppose Southern resource stocks are slightly below Z_S^c. After trade begins, Northern stocks will eventually be large enough (regardless of their initial condition) so that North exports the resource-intensive good. Southern stocks recover and eventually reach their high steady state. At some point South begins to export the resource-intensive good. The relevant comparison for South is between a high and a low steady state, and South is better off at the former. The relevant comparison for North is between autarkic and free-trade high steady states, and we can show that North prefers the latter. North does well by doing good. In this scenario, trade causes North to "pull up" South, after which South returns the favor.

These scenarios illustrate the range of possible outcomes in moving from autarky to trade.

The resilience of the environment, measured by the growth parameter η, is one determinant of which outcome occurs. Our model implies that "environmental resilience" (a high growth rate) reduces the likelihood of the scenario in which trade exacerbates market failures and lowers welfare in both regions in the long run (even if it might improve welfare in the short run). The level of Southern stocks at the time of the policy change is the other factor that determines whether trade is Pareto inferior or superior in the long run. The scenario in which trade lowers long-run welfare requires large Southern stocks, and the scenario in which it improves long-run welfare requires small stocks. Thus, trade may offer a helping hand to the South, especially when South experiences severe environmental problems. A resource poor South may benefit most from international trade, contrary to the popular arguments of environmentalists.

7.2 Long-Run Effects of Environmental Reform

In this section we consider separately the long-run effects of environmental reform under autarky and under trade. We then summarize the differing effects of reform in the short and the long run, and under free trade and autarky.

Long-Run Effects of Reform Under Autarky

Our assumptions about the utility and production functions imply that η^{LA} is independent of the environmental distortion; thus $d\eta^{LA}/d\delta = 0$. As a country's distortion δ increases, it is more likely that it reaches a low steady state, so $d\eta^{HA}/d\delta > 0$. These conclusions imply that if $\eta < \eta^{LA}$, the economy moves to the low steady state; reform under autarky cannot enable the economy to escape and move to a high steady state. Similarly, if $\eta > \eta^{HA}$, the economy reaches the high steady state with or without reform (since reform reduces η^{HA}).

Reform has no long-run effects.

For the intermediate case, $\eta^{LA} < \eta < \eta^{HA}$, the magnitude of the reform is important. If the reform is large, the reduction in η^{HA} can be great enough to reverse the inequality $\eta < \eta^{HA}$; in this case, reform removes the low steady state as a possibility. This large reform qualitatively improves the long-run welfare for small initial stocks, since the stock after reform approaches a high rather than a low steady state. But for large initial stocks, the stock would have approached a high steady state even without reform, so the reform does not have any qualitative long-run effects.

Long-Run Effects Under Trade

Recall from Section 5 that under free trade, the extraction levels of the two countries at the high steady state depends only on the *relative* distortions of the two countries, δ_S/δ_N. Consequently, the critical value η^{LT} also depends only on δ_S/δ_N, rather than the absolute values of the two distortions. Since differences between the two countries' distortions lead to inefficient allocation of the extraction efforts, it is less likely that they will reach the low steady state when they harmonize their environmental distortions. That is, η^{LT} decreases as the two distortions become less different:

$$\frac{d\eta^{LT}}{d(\delta_S/\delta_N)} > 0. \tag{3}$$

Harmonization of policies, achieved by either an improvement in Southern standards, or a deterioration in Northern standards, reduces δ_S/δ_N and thus η^{LT}. If $\eta < \eta^{LT}(\delta_S/\delta_N)$ prior to harmonization, there is only a low steady state. Harmonization can reverse this inequality, thereby creating a high steady state. If the initial stocks, $\boldsymbol{Z}_0$, are sufficiently large,

harmonization then causes the economies to move toward the high steady state. In this case, harmonization benefits both North and South in the long run. Here, harmonization shifts production of the resource-intensive good away from South, possibly altering the nations' apparent comparative advantage and reversing the direction of trade for a time. The lower level of exploitation enables South's stocks to recover. In the long run, South exports steel and North's stocks also recover.

Unilateral reform in North, which represents a movement away from harmonization, increases η^{LT}. Suppose, for example, that pre-reform $\eta > \eta^{LT}$ and $\boldsymbol{Z}_0$ lies above the convergent saddle path through $\boldsymbol{Z_u}$; in this case the economies move toward $\boldsymbol{Z_h}$. If after Northern reform, $\eta < \eta^{LT}$, the economies approach the low steady state $\boldsymbol{Z_l}$. Northern reform harms both countries in the long run.

The critical value η^{HT} depends on both the relative and absolute values of δ_S and δ_N. Southern reform decreases both the absolute distortion in South and its distortion relative to North. This reform has an unambiguously beneficial long-run effect, since it reduces the range of values of η under which the low steady states exist (i.e., it increases the range of values for which the unique steady state is high):

$$d\eta^{HT}/d\delta_S > 0. \tag{4}$$

Southern reform may cause the regime to change from the case of multiple steady states to the case with only a high steady state. If this occurs, Southern reform causes the economies to move to a high steady state even if they were previously trapped at a low steady state.

The long-run effect of Northern reform is ambiguous because it increases the relative distortions but decreases an absolute distortion. The effect of this reform on η^{HT} depends

on which of the two influences is stronger. In particular, it depends on the initial difference between δ_S and δ_N and some parameters indicating the "severity of the environmental problem," such as the congestion parameter γ. If the resource is not extremely congested (i.e., if γ is low), the absolute effect of Northern reform always dominates the relative effect. In this case, Northern reform decreases the critical value η^{HT}. If, on the other hand, the environment is very congested, then either the absolute or relative effect may dominate. If the difference between the property rights is large, the relative effect dominates, and Northern reform increases the critical value η^{HT}. If the difference between the distortions is small, the absolute effect dominates, and Northern reform decreases the critical value η^{HT}.

The fact that upward harmonization (through reducing δ_S) certainly decreases η^{HT}, but downward harmonization (through increasing δ_N) may increase η^{HT}, argues in favor of upward rather than downward harmonization. This argument is based on the long-run effects of reform.

The Different Effects of Reform

The dynamic and static effects of reform differ under free trade. If stocks are large enough to support full employment of labor (so that "trade matters") and if factor prices are equalized, instantaneous aggregate welfare depends only on relative distortions. Harmonization, whether achieved by upgrading Southern standards or degrading Northern standards, has the same instantaneous effect on aggregate welfare. In the long run, however, absolute as well as relative levels of standards are important. Harmonization upwards is more likely than harmonization downwards to increase long run stocks and welfare.

The dynamic effects of reform depend on the trade regime. In a closed economy, reform does not alter the critical value η^{LA}, below which only a low steady state exists. If a country

under autarky is trapped in a steady state with low environmental stocks, technology and preferences determine its destiny. Environmental reform cannot lead to high steady state stocks. In contrast, if open economies are trapped in a low steady state, harmonization of environmental policies (which reduces η^{LT}) may enable them to escape to a high steady state.

In a closed economy, reform always reduces the critical value η^{HA}, above which only a high steady state exists. Therefore, if both the high and low steady states exist in an autarkic economy, reform might eliminate the low steady state, ensuring that the economy reaches the high steady state. With open economies, reform in the more distorted economy reduces the critical value η^{HT} above which only a high steady state exists. Reform in the less distorted economy, which reduces harmonization, may increase this critical value. Therefore, in open economies, reform against harmonization can either increase or decrease the danger that environmental stocks move to a low steady state.

In addition to illustrating these possibilities, the model shows how the plausibility of a particular outcome is related to the intrinsic growth rate of the environment. If η is small, we consider the environment to be "fragile", in the sense that it regenerates slowly. In this situation, changes in η^{LT} and η^{LA} are more important than are changes in η^{HT} or η^{HA} (since the actual value of η is more likely to be close to the first pair of critical values). Thus, "fragility" of the environment makes it more likely that harmonization – even if achieved by lower standards in North – improves the environment and welfare in both the short and the long run. If, on the other hand, the environment is "resilient" (η is close to η^{HT} or η^{HA}), unilateral reform in North may lead to long-run improvements, at the cost of short-run welfare losses.

8 Discussions and Conclusion

We have examined the effects of trade liberalization and environmental reform in a simple dynamic general equilibrium model in which two countries, North and South, differ in two respects. These two differences cause autarkic equilibrium prices to differ, and therefore lead to trade. The first difference is institutional. The two countries have different degrees of environmental distortion or different property rights for an environmental resource. The distortion is greater in South, which tends to give South an apparent comparative advantage in the environment-intensive good. The second difference is that the environmental stocks, and thus the costs of producing the environment-intensive good, may differ in the two countries. This difference – unlike the institutional difference – is a standard motivation for trade. At a point in time the stock levels are pre-determined. However, environmental stocks evolve endogenously, depending on how heavily the resource is exploited. Over time, factor endowments are endogenous and the pattern of trade can change.

We used the model to address two related but distinct issues, about which environmentalists and economists have a history of disagreement. The first concerns the welfare effects of trade liberalization, which we modeled by comparing autarky and free trade. The second concerns the effect of unilateral environmental reform and of harmonization. We defined harmonization as a change that makes the distortions in the two countries more similar; harmonization is consistent with a reduced environmental distortion in South, or an increased distortion in North.

We emphasized at the outset that in a world with more than one distortion, the welfare effect of reducing a single distortion is likely to be ambiguous. We also emphasized that trade restrictions are not the appropriate policy for dealing with environmental problems, and we cautioned against using the results of our analysis to promote an anti-trade or anti-property

rights agenda. Our model – like any analytic model – ignores too many factors that we know to be important, to lead to unequivocal policy conclusions. For example, we ignore difference in tastes and technology and factor endowments other than the environmental stocks; we ignore other dynamic variables, such as technology and capital stocks; we assume that the level of the environmental distortion is exogenous, when in fact it might respond to changes in income or other endogenous (e.g. political) variables. Finally, we used specific functional forms that limit substitutability in consumption and production.

On balance, we think that our model has more of an "environmentalist's slant" than an "economist's slant". The model emphasizes an environmentally related market failure and ignores many of the reasons for trade that are standard in economic models. Therefore, it is not surprising that the model supports certain positions favored by environmentalists, such as the beneficial effects (at least in the short run) of harmonization of environmental policies; the model assumes away the reasons why economists are skeptical of the benefits of harmonization. In evaluating this conclusion, the reader has to balance the relative importance of the different reasons for trade in the real world – the reasons that our model emphasizes and those that it ignores.

Despite this environmental slant, the model has implications that are familiar to economists. For example, it explains why, under some conditions, "downward harmonization" is as beneficial as "upward harmonization". This extreme result is due to the assumed lack of substitutability in our model, but it would survive (in a weaker form) if there was some substitutability. Also, the model demonstrates that trade is certainly beneficial in the short run if the stock differences are sufficiently large relative to the institutional differences.

However, we believe that the main contribution of our analysis is the light it sheds on differences between short and long-run policy effects, and on the manner in which these

effects depend on the "fragility" of the environment. There are many ways that one could measure environmental fragility; in our setting, it is natural to consider a resource that regenerates slowly as being fragile.

Our model contains the possibility of multiple steady states; with this possibility, the long-run equilibrium depends on the initial environmental stocks. A policy reform – liberalized trade or a reduced environmental distortion – can change the nature of the steady state to which the economy converges, leading to long-run qualitative effects that are much different from the short-run effects.

Although the relation between long-run policy effects and the fragility of the environment is rather complex (even in our simple model), one clear and important tendency emerges. When the environment is fragile, it is more likely that a movement from autarky to free trade reduces long-run welfare, and it is more likely that policy harmonization is beneficial under trade. Similarly, when the environment is resilient, it is more likely that the movement from autarky to trade improves welfare; it is also more likely that environmental reform – even when this increases the difference between environmental policies – improves welfare.

The model's implications are consistent with the beliefs of the "typical" environmentalist or economist; the implications depend on whether the environment is fragile or resilient. Since it seems likely that environmentalists (relative to economists) are more apt to view the environment as being fragile, the model provides a partial explanation for the differing views of the two groups. Even such a partial explanation is useful in promoting dialog between the groups. The groups' differing policy conclusions are not necessarily the result of irreconcilable world-views, but a consequence of different beliefs about unknown facts of the world – facts about which we can hope to learn more.

There can, of course, be no definitive answer to questions such as "Is trade good for the

environment?" or "Is policy harmonization a desirable goal?". However, if opposing groups are less dogmatic about their answers to these kinds of questions, there is greater potential for designing policies that liberalize trade and protect the environment.

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