May 21, 1997

The Uncertain Benefits of Environmental Reform in Open Economies

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We compare the instantaneous and the long run effects of environmental reform in closed and open economies. Harmonization upward (decreasing distortions where they are most severe) or harmonization downward (increasing distortions where they are less severe), both tend to increase instantaneous world welfare. Environmental reform in a country with less severe distortions works against harmonization and may decrease welfare. Harmonization upward has more beneficial long-run effects than harmonization downward, and also provides higher expected instantaneous benefits if the current stock is uncertain. In the short run there is a conflict between environmental protection and reduction of unemployment, but in the long run the two goals are consistent.

JEL Classification Numbers: Q20, F10, H23

Keywords: International trade and the environment; environmental policy reform; international harmonization of environmental policies; environmental dynamics and trade.

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Table of Contents

Figures

Non-Technical Summary

The Uncertain Benefits of Environmental Reform in Open Economies

Environmental reforms which in a closed economy would benefit the environment and increase welfare may have the opposite effect in the presence of international trade. These unintended consequences are likely where the reforming country begins with a higher level of environmental protection. In that case, environmental reform might be counterproductive in an open economy.

In our two-country model there exists a single environmental distortion in each country. Under autarky, a reform which reduces the domestic distortion improves a country's welfare. With trade, there are two relevant distortions. The theory of the second best alerts us to the possibility that reform in one country, i.e., the reduction of its distortion, does not necessarily increase welfare in either country.

Economists usually argue against harmonization of environmental policies for local pollution problems. The basis for this position is the belief that differences in policies reflect differences in tastes, technology, or endowments. This argument against harmonization disappears if policy differences are caused by cross-country differences in market failures.

Differences in market failure, like differences in technology or factor endownments, can cause of international trade. When environmental reform occurs in the country which initially has a smaller environmental distortion, the difference between the countries increases. To the extent that trade is driven by this difference, trade is also likely to increase, and the welfare effects of reform are ambiguous.

We use a general equilibrium model to compare the short and long run effects of environmental reform in open and closed economies. In open economies, relative distortions across countries, in addition to absolute distortions, are important. In the short run harmonization can improve welfare even if it involves lowering standards in one country ("downward harmonization"). Dynamic analysis provides an important reason for preferring upward to downward harmonization. Non-negligible changes in policies can have dramatic effects in economies with multiple equilibria. Upward harmonization increases the chance of arriving at a high steady state. Downward harmonization, despite the fact that it may have identical instantaneous (aggregate) effects, can reduce the chance of arriving at a high steady state.

Increasingly open markets requires that environmentalists adopt a global perspective, even for local pollution problems. It is important to compare the benefits of investing, in different countries, resources that promote reform. Reform in the most highly distorted economies decreases both absolute distortions and differences in distortions. Therefore, lobbying for reform in these countries may have the highest environmental payoff, even if reform is more difficult to achieve there. Developing countries sometimes advise environmentalists to put their own house in order before attempting to export environmental reform. This is bad advice, especially from the standpoint of developing nations likely to have relatively serious environmental distortions.

We also study the relation between the goals of improving the environment and reducing unemployment. In the short run the two policy goals may conflict, but in the long run they are compatible when increased environmental stocks increase the demand for labor.

1. Introduction

Environmental reforms which in a closed economy would benefit the environment and increase welfare, may have the opposite effect in the presence of international trade. These unintended consequences are likely where the reforming country begins with a higher level of environmental protection. Even if the reforming country benefits in the short run, both it and other countries may be harmed in the long run. These possibilities are related to, but distinct from, environmentalists' usual trade-related concern: International trade makes domestic environmental reform more difficult and expensive because it allows countries with lower environmental standards to attract polluting industries. Since reforming countries are reluctant to lose the jobs and profits associated with these industries, international trade supposedly makes them less willing to protect the domestic environment. Our point, however, is not that international trade makes it more expensive and politically difficult to implement environmental reform, but that reform might be counterproductive in an open economy.

This possibility is a special case of the theory of the second best. Suppose, for example, that in each of two countries there exists an environmental distortion, which is the only market imperfection. Under autarky, a reform which reduces the domestic distortion improves a country's welfare. With trade, there are two relevant distortions. The theory of the second best alerts us to the possibility that reform in one country, i.e., the reduction of its distortion, does not necessarily increase welfare in either country.

Inter-industry trade occurs because of differences between countries, such as differences in technology, factor endowments, or tastes. A number of recent papers, including Chichiliniski (1993, 1994), Copeland and Taylor (1994, 1995) Brander and Taylor (1996) and Karp, Sacheti and Zhao (KSZ;1997), have emphasized that differences in environmental regimes also provide an impetus for trade. When environmental reform occurs in the country which initially has a smaller environmental distortion, the difference between the countries increases. To the extent that trade is driven by this difference, trade is also likely to increase, and the welfare effects of reform are

ambiguous.

Viewed in this light, the observation that domestic environmental reform might be counterproductive is quite obvious. Although not surprising to trade theorists, the observation is important for policy discussions, and appears to have been largely ignored. These discussions have concentrated on the possibility that trade encourages countries to lower (or fail to tighten) environmental regulations, in order to obtain competitive advantage in certain industries. Whatever the merits of this particular anti-free-trade argument, it is unlikely to alter the movement toward trade liberalization. The focus should therefore shift to the appropriate design of environmental policy in an open economy.[1]

An important issue in designing such a policy concerns cross-country harmonization of policies. In a two-country model, reform in the country which initially has the larger environmental distortion narrows the cross-country difference in distortions, and therefore represents a "harmonization" of policies. Reform in the country with the smaller distortion, on the other hand, is a movement away from harmonization of policies. Economists and environmentalists have disagreed on the merits of harmonization[2].

Environmentalists think that competitive pressures, which are heightened by trade liberalization, create a danger of a "race to the bottom" in environmental standards. They conclude that harmonization of policies is important to prevent this race. However, if their

[1] A number of papers have studied environmental reform in open economies. Markusen (1975) and Krutilla (1991) analyze the terms of trade effects of environmental policies in a static setting. Copeland (1991) studies a small country model with several instruments. Markusen et al (1993) analyze the effect of policy on plant location under imperfect competition. Ulph (1994) surveys recent work in the field.

[2] The arguments for and against harmonization are presented in many articles, including: Agras et al (1994); Bhagwati (1996); Bhagwati and Srinivasan (1996); Charnovitz (1993); Hoel (1993); Levinson (1996); Klevorick (1996); Merchant and Ballenger (1994); Nordhaus (1994); Rauscher (1994); Robertson (1992); Ulph (1994); Wilson (1996). Krugman (1997) summarizes many of these arguments.

concern is with falling standards, then the remedy is to install mechanisms to maintain or improve environmental protection everywhere. It is misleading to speak of harmonization when environmentalists would be happy if standards were tightened everywhere, even if this meant that cross-country differences increased (i.e., that standards became "less harmonious").

Economists tend to oppose pressures for harmonization, arguing that differences in standards may have a number of rational explanations. For example, they may reflect differences in income, tastes, capital stocks, resource endowments, or a variety of other factors that contribute to inter-industry trade. In this case, harmonization is an attempt to thwart the efficient workings of the market. We agree that these considerations are important, but believe that in many cases differences in standards simply reflect different degrees of market failure. Property rights may be weaker in some countries, and some countries may have been more successful in dealing with externalities. If this is the correct explanation for different standards, the presumption that harmonization reduces welfare is incorrect.

Our model supports harmonization, but does so in a rather heretical manner. "Harmonization upward" benefits the environment and improves welfare, even if there is no danger of a race to the bottom. In addition, in many cases "harmonization downward" is also beneficial. However, even in a simple model which emphasizes the importance of relative differences in market failure, we find reasons why harmonization upward is better than harmonization downward.

An international dimension of environmental policy is usually associated with transboundary environmental problems. For these problems, there is widespread agreement that international cooperation is important. However, international trade causes "purely local" (in the physical sense) environmental problems in one country to affect those in another. Local environmental distortions affect world prices, which influence producers and consumers in other countries. Their decisions affect the severity of their own "local" environmental problems. For transboundary environmental problems, the international dimension to policy is obvious and exists with or without international trade. For local environmental problems, trade *creates* the

international policy dimension. We consider only local environmental problems, since the role for international environmental policy is probably less obvious, but no less important, for these.

Section 2 describes the autarkic and trade equilibria. This model was sketched by Chichiliniski (1994) and elaborated by KSZ (1997), who used it to compare welfare under autarky and trade, taking environmental policy as given. We use the model to show the different effects of policy reform under autarky and trade. Section 3 compares the static effects of reform in the two regimes, and Section 4 compares the dynamic effects. Section 5 contains concluding comments.

2. The Autarkic and Trade Equilibria

We describe the model and summarize the characteristics of the autarkic and trade equilibria which are important for our results concerning the effects of reform. Appendix A contains the algebraic details.

2.1. Description of the Model.

Figure 1 is a flow chart of the economy, which produces two goods: the "subsistence good" A, which we choose as the numeraire, and the "composite good" B, which has price p. The representative consumer attempts to consume A^* units of A. If her income, y, is less than A^*, she spends everything on good A, receiving utility y (equal to the consumption of A). If her income exceeds A^*, she buys A^* units of good A and $(y-A^*)/p$ units of B, resulting in utility $A^* + (y-A^*)/p$. These preferences provide a simple way to describe a situation where the income elasticity for the subsistence good is very high at low income and is very low at high income. Our assumption of discontinuous income elasticity is probably unrealistic, but not more so than the usual assumption of constant income elasticity. We assume that the representative consumer's income exceeds A^*. This assumption, which requires that the environmental stock is sufficiently large, simplifies calculations but is not essential.

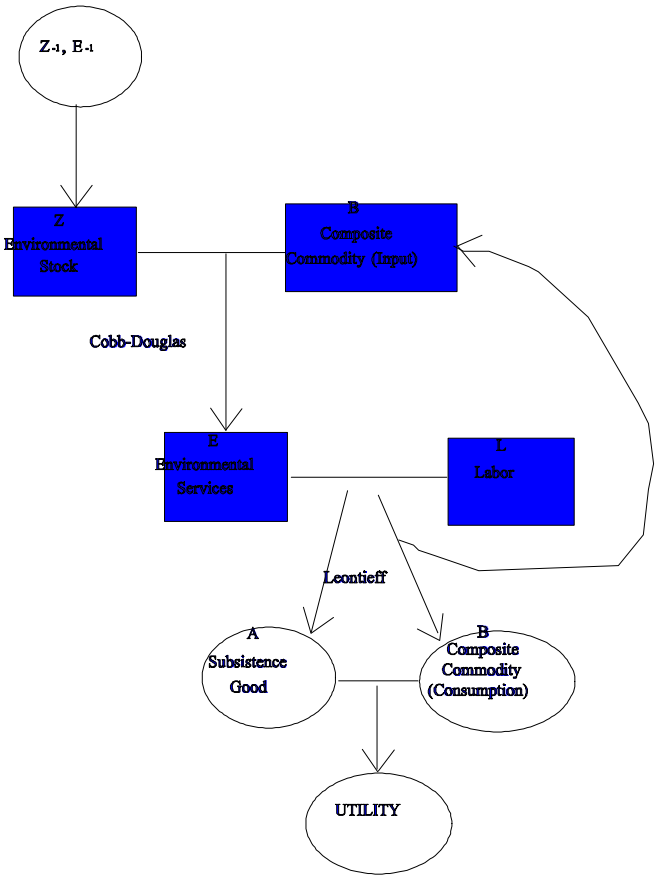

Figure 1: Flow Chart of the Economy

The two factors of production are labor, L, the supply of which is fixed and exogenous, and environmental services, E, the supply of which changes endogenously over time. Competitive producers combine these factors, using Leontieff technology, to produce goods A and B. Good B, in addition to being consumed, is used in conjunction with the current environmental stock, Z, to produce environmental services E. The stock of Z is fixed at a point in time; larger stocks decrease the costs of producing E. The change in the environmental stock depends on the current

environmental stock and the flow of environmental services.

To help fix ideas, we can think of good A as food, good B 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 agriculture and steel production. A low income economy uses steel only for pipes, but a richer economy also consumes cars. Water in lakes is a renewable resource, which provides benefits only as a source of a factor of production. (The consumer does not fish or swim.) A larger stock of water means that supplies are closer to production, so less steel is needed to obtain useable water.

We denote the amount of B used in the production of E as B^e. For a given level of the stock of Z, a given price of output E, and assuming decreasing returns to scale in B^e, the value of B's average and marginal product is decreasing, as shown in Figure 2. *Static* efficiency, which ignores that both the future stock of Z and future extraction costs depend on current extraction, requires setting the value of the marginal product equal to p, using B_1 units of the input. In this case, E-producers have perfect *static* property rights. If E-producers choose their input level and receive a share of output proportional to their share of total inputs, the Nash equilibrium level of B^e exceeds B_1. The level approaches B_2 (where the value of average product equals input price) as the number of producers approaches infinity. In that case there is open access, or no property rights. If E-producers have some degree of *dynamic* property rights, and in addition have perfect static property rights, they would impute a positive shadow value to the stock. In that case, the equilibrium amount of B^e is less than B_1. We consider the situation where producers have only imperfect static property rights, so that the equilibrium B^e exceeds B_1.

In order to obtain a closed form solution, we assume a Cobb-Douglas production function $E = (B^eZ)^{.5}$, which leads to a supply function $E = \delta Zp^e/p$, where p^e is the price of E and the parameter δ measures the environmental distortion. The supply of E depends on δZ, which we define as "apparent stock", to distinguish it from the physical stock, Z. A larger environmental distortion (larger δ) implies a larger apparent stock, and a larger supply of the factor E, for given Z and prices. For zero property rights, $\delta = 1$; for perfect static property rights, $\delta = .5$. We treat δ as a fixed parameter, and represent reform (e.g., an improvement in property rights or a tightening of environmental standards) as a reduction in δ. Provided that the initial value of δ exceeds .5, as we assume throughout the paper, a small reduction of δ necessarily increases efficiency (for given Z and price), in addition to reducing the current supply of E.[3]

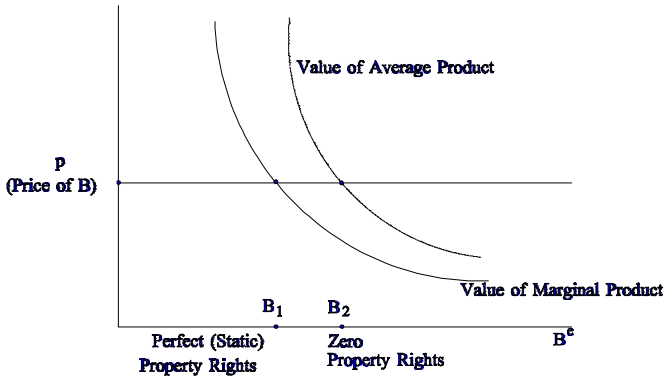

Figure 2: The Environmental Distortion

Economies are identical except for their value of δ and (possibly) their stock levels. We use subscripts N and S (for North and South) to denote country-specific values of these variables. We assume that $\delta_S > \delta_N$, so the environmental distortion is worse in South. For the trade equilibria we restrict attention to the case where both economies are diversified in production, so that factor prices are equal.

2.2. Description of the Equilibria

In both regimes, there are two possibilities: either labor is fully employed, or some labor is

[3] If $\delta < .5$, producers impute a positive shadow value to the stock, i.e., producers have some dynamic property rights. In this case, however, the imputed shadow value, and thus the value of δ, should vary endogenously with Z. We ignore this complication by focusing on the situation where static property rights are imperfect, so $\delta > .5$.

unemployed. Appendix A gives the formulae for the price of B and extraction of E in the different equilibria. First, suppose that labor is fully employed under both trade and autarky.[4] Since the world production of A is $2A^*$ in both cases, we know the aggregate (world-wide) amount of L and E used in sector A. Consequently we know the amount of labor available for sector B. Given the assumptions of full employment and Leontief technology, we know the aggregate amount of E used in sector B. Thus, we know the aggregate amount of E used by the world. This amount is the same under free trade and autarky, and is independent of the values of δ_i. However, the amount of extraction in each country does depend on δ_i.

Now consider the case where labor is unemployed in both countries, in autarky. In this case, there is only one constraining factor of production, E, so we have the standard Ricardian model. In view of the assumption that countries have the same technology, there is no reason for trade: the autarkic and free trade equilibria are identical. In this case also the aggregate supply of E is the same under free trade and autarky. However, both the aggregate and individual country supplies of E now depend on δ_i.

In autarky, labor is fully employed in country i if and only if the apparent stock, $\delta_i Z_i$, is sufficiently large, i.e. if and only if Z_i exceeds a critical value, which we denote $Z^c(\delta_i)$. This result is intuitive. Labor is fully employed if and only if there is sufficient E to combine with it, and the supply of E depends on $\delta_i Z_i$. Similarly, with trade, labor is fully employed if and only if the world supply of E is sufficiently large, which in turn requires that world aggregate apparent stocks, $\psi \equiv \delta_S Z_S + \delta_N Z_N$, exceed a critical level, which we denote ψ^c. This critical level is independent of δ_i, although Ψ of course depends on δ_i.

The remaining two possibilities are: (i) labor is fully employed under free trade ($\psi > \psi^c$) but unemployed in one country under autarky ($Z_i < Z^c(\delta_i)$ for one country); or (ii) labor is

[4] If labor is fully employed in one country, its price is positive. Under trade and with the assumption of factor price equalization, labor must also have a positive price and be fully employed in the other country. Under autarky, labor might be fully employed in one country and unemployed in the other.

unemployed under free trade ($\psi < \psi^c$) but fully employed in one country under autarky ($Z_i > Z^c(\delta_i)$ for one country). Figure 3 shows the regions of (Z_S,Z_N) space where the various possibilities occur.[5] In region I there is full employment under autarky and trade; in region IV, there is unemployment under both regimes. Regions II, III, V and VI comprise the sets of stocks where the remaining possibilities occur. For example, in region II labor is fully employed under trade, but unemployed in South under autarky. We concentrate on regions I and IV, in order to make our point about environmental reform as simply as possible.

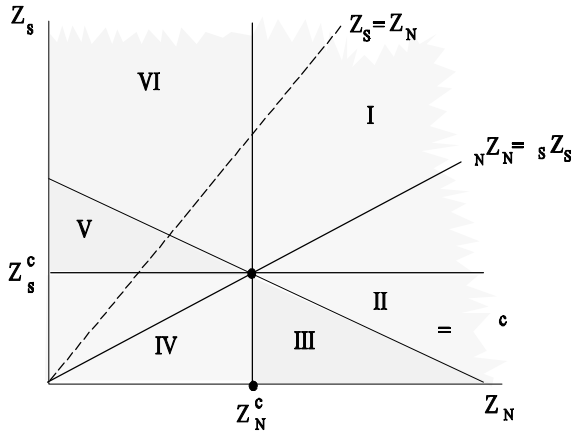

Figure 3: Regions of State Space

From the Heckscher-Ohlin-Samuelson theorem, and the assumption that the stock of L is the same in both countries, we know that the country with the larger supply of E exports the resource intensive good. Since supply of E_i is proportional to i's apparent stocks (recall that $E_i = \delta_i Z_i p^e/p$), a country's share of world supply of E equals its share of world apparent stocks. The country with the larger apparent stock of resource exports the resource intensive good. For stock combinations below the No-Trade-Line (NTL) defined by $\delta_N Z_N = \delta_S Z_S$, North exports the resource intensive good. For stock combinations in the intersection of region I and the cone formed by the NTL and the 45^o line, South has an "apparent" but not a "real" comparative advantage in the resource intensive good. For these stock combinations, South exports the resource intensive good because its environmental distortion is

[5] Near the axes one country is specialized, and our description is no longer correct. Thus all of our remarks apply to the "cone of diversification". We do not include this cone in the figure in order to avoid clutter, and because we will not discuss regions of specialization. Similarly, our comments do not apply to an area in region IV near the origin, where the countries are too poor to be able to consume A^*. Suitable restrictions on parameters ensure that after excluding this area, region IV is not empty.

greater, despite the fact that its relative extraction costs are higher.

3. Static Effects of Policy Reform

We first consider the instantaneous welfare effects of environmental reform (a reduction in δ_i) under autarky, and then under free trade. We assume that $\delta_i > .5$, so that static property rights are imperfect.

3.1. Static Effects of Rerform under Autarky

The situation under autarky is straightforward; here we drop the country subscript. We noted in the previous section that for $Z > Z^c(\delta)$, where labor is fully employed, the equilibrium supply of E is independent of δ, because of our assumptions about demand and Leontieff technology. Consequently, for $Z > Z^c$ environmental reform has no effect on static welfare under autarky.

For $Z < Z^c$, however, domestic welfare (consumption) *and unemployment* are decreasing in δ. When labor is unemployed its price is 0, and national income equals rents in the E-producing sector, $p^eE(Z,B^e) - pB^e$. A larger value of δ implies a larger gap between the value of marginal product and price, and thus lower rents and lower welfare. An increase in δ also raises the apparent resource stock, resulting in larger extraction of E, which requires that more labor is used in the production of B.

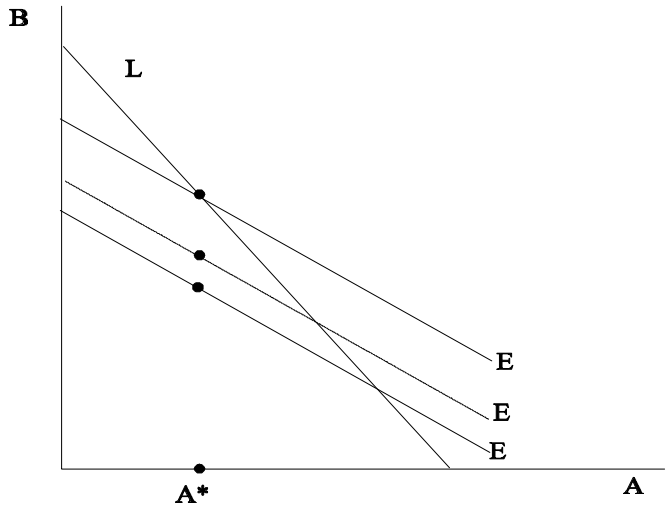

Figure 4: Effect of δ and Z on Output

Figure 4 illustrates the effects of changing δ for different values of Z, under the assumption that the stock is large enough for the country to be able to consume A^*. The line labelled L shows production pairs consistent with full employment of labor. The lines E′, E′′ and E′′′ are graphs of the environmental constraint for different values of E. The relative slopes of the lines imply that good B uses E intensively, but this assumption has no bearing on the results. If $Z > Z^c$, the equilibrium level of E must equal E′′′, with full employment of both factors and production of A^*. In this case a change in δ does not alter the level of E. For example, if the level of E were to rise following an increase in δ, maintaining production of A^* requires unemployment of E, and thus $p^e = 0$. In that case, however, no E would be produced, so this could not be an equilibrium.

If, however, $Z < Z^c$, the equilibrium level of E is at a level such as E′, with some labor unemployed, and production of A^*. If δ increases, the supply of E increases to E′′, and production of B increases. However, the increased supply of E requires higher input use, B^e. Since the value of the marginal product of B was already below its price, the increase in B^e must exceed the increased production of B. Thus, the amount of B available for consumption, and hence welfare, decreases. The increase of E from E′ to E′′ shifts the equilibrium closer to the full employment line L, and therefore decreases unemployment.

In this model, environmental reform (reducing δ) has no static welfare effect when the environmental stock is large, but improves welfare when the environmental stock is small. Although the extreme nature of this conclusion is unrealistic, it does have the appealing implication that reform is most important when environmental stocks are small. An

environmentally rich country (large Z) does not benefit from reform in the short run. Reform does benefit an environmentally poor country, even in the short run.

The model also supports the widely held belief that environmental and employment goals conflict, at least in the short run, for low environmental stocks. Greater environmental protection improves static welfare, but at the cost of increasing unemployment. Governments which are more concerned with employment than with national income may be reluctant to adopt stricter environmental standards.

3.2. Static Effects of Reform under Free Trade

We saw that for stocks in region IV, autarky and free trade are equivalent. In this region, the benefits of environmental reform are also the same under trade and autarky. In region I, aggregate welfare (consumption of B) depends only on the relative distortions, but the distribution of welfare also depends on absolute levels of the distortions.

We noted that in region I with trade, aggregate supply of the factor E is independent of δ_i, but each country's share of that factor is equal to its share of aggregate apparent stocks. Environmental reform in country i decreases its share of world apparent stocks, causing production of E to shift to the other country. Given that the world supply of E is independent of δ_S and δ_N, as is the world supply of A (= $2A^*$), the supply of B must also be independent of δ_i. However, since each country's share of aggregate E depends on the δ's, the amount of B used to produce E, B + B, also depends on the δ's. Therefore the aggregate *consumption of B* (= production B - B - B), which is a measure of world welfare, depends on the δ's. Reform in North shifts production of E to South, where the marginal value of product is already lower (because $\delta_S > \delta_N$). This reform therefore decreases the amount of B available for consumption, and lowers world welfare. (KSZ, Proposition 6.) Reform in South increases world welfare.

The effect of reform on individual countries' welfare is more complicated, because reform causes a change in the terms of trade in addition to a reallocation of production of E. In Appendix B.1 we show that if $\delta_S > 3/4$, South always benefits from domestic reform when stocks are in region I.[6] There is a line from the origin with slope $dZ_S/dZ_N = (3 - 4\delta_S)\delta_N/\delta_S$, lying below the No Trade Line (NTL), which we refer to as the Southern Regret Line (SRL) (Figure 5). For stocks below the SRL, South loses from a reduction in δ_S, and for stocks above that line, South benefits from reform. Reform in South causes a reduction in its supply of E. In order for North's supply to increase, the equilibrium p^e/p must increase. By the Stopler-Samuelson theorem, and our assumption that good B is E-intensive, p must increase. Above the NTL, where South exports B, the increase in p is an improvement in South's terms of trade, which reinforces the beneficial effect of reducing the market imperfection. For stocks below the NTL, where South imports B, the increase in p is a deterioration in South's terms of trade. If South is a sufficiently large importer of B, i.e. if stocks are sufficiently far below the NTL (more precisely, below the SRL), the deterioration in South's terms of trade more than offsets the direct benefit of reducing South's gap between the value of marginal product and price in the E-sector. In this situation, South is harmed by its reform.

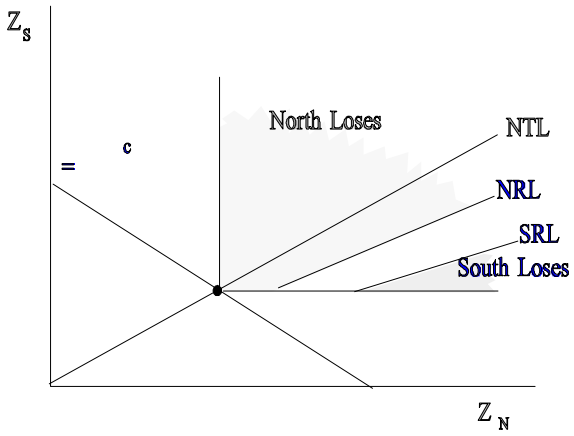

Figure 5: Country Effects of Reform in South

Figure 5 also shows a line from the origin with slope $dZ_S/dZ_N = (3 - 4\delta_N)\delta_N/\delta_S$, labelled the Northern Regret Line (NRL), lying between the NTL and the SRL. For stocks above this line, North loses from Southern reform, and for stocks below the line, North benefits. Southern reform: (i) increases p and (ii) causes production of E to shift to the North, increasing the gap

[6] The analysis of regions II, III, V and VI yields no additional insight, so for the sake of brevity we ignore these.

between the value of marginal product and p in North's E-sector. The second effect always harms North, and the first benefits North only if North exports B. Thus, North benefits from Southern reform only if North is a sufficiently large exporter of B, which requires that stocks lie below the NRL. In order for both countries to benefit from Southern reform, stocks must lie in the region between the NRL and the SRL.

The analysis of reform in North is similar. North always benefits from its reform unless it is a sufficiently large importer of B; South always looses unless it is a sufficiently large exporter of B.

Equal-proportionate reform in the two countries, which leaves relative distortions unchanged, does not alter E_i or aggregate welfare. However, this reform reduces world apparent resource stocks. In order to maintain the same level of extraction, the price of the resource intensive good (B, in our example) must rise. Equal-proportionate reform thus benefits exporters of the environmentally intensive good and harms importers. Therefore, when evaluating a policy change which leaves δ_S/δ_N unaltered, exporters of B prefer a "race to the top", and importers of B prefer a "race to the bottom".

3.3. Discussion of Static Effects

Remark 1 summarizes the static effects of reform:

Remark 1. *(i) Under autarky, for sufficiently small stocks, environmental reform reduces extraction, increases consumption (and thus welfare) and increases unemployment. For large environmental stocks, the environmental distortion is irrelevant and reform has no effect on welfare or employment under autarky. (ii) Under free trade, with sufficiently low stocks in both countries (region IV), reform has the same welfare effect as under autarky.*[7] *(iii) Under free trade*

[7] The effect on unemployment is more complicated, because the free trade equilibrium is indeterminate in region IV. There we have the one-factor Ricardian model with identical technology and consumption fixed at A^* in both countries. A range of production points are consistent with free trade equilibria. Each of these involves the same level of welfare and supply of the factor E_i, but each has a different level of unemployment. The price of labor is zero, so the amount of employment does not affect welfare. We can show that reform in one country never

with sufficiently high stocks in both countries (region I) Southern reform: (a) increases world welfare, (b) harms North unless North is a sufficiently large exporter of B, (c) benefits South unless South is a sufficiently large importer of B, and (d) has no effect on unemployment. (iv) In region I, Northern reform: (a) decreases world welfare, (b) harms South unless South is a sufficiently large exporter of B, (c) benefits North unless North is a sufficiently large importer of B, and (d) has no effect on unemployment (v) In region I, aggregate welfare (i.e., aggregate consumption) depends only on relative distortions, but the distribution of welfare also depends on levels of distortions.●

These results illustrate the importance of the trade regime in designing environmental reform. The assumptions of our model lead to the conclusion that whenever "trade matters" ($\psi > \psi^c$, e.g. in region I), world welfare depends only on the relative distortions, δ_S/δ_N, not on the levels of the distortions. In this case, "harmonization of policies" always improves world welfare: a "race to the bottom" can be as beneficial as decreasing the distortions in both countries. This conclusion does not seem surprising to economists, accustomed to recognizing that relative prices, rather than price levels, are important.[8] In a more general model, world welfare would depend on both the absolute and relative levels of distortions. In that case, the argument for harmonizing environmental policies would remain, and it would still be *possible*, but not certain, that lowering environmental standards in North would improve welfare. However, harmonization upwards, by improving Southern standards, would certainly improve welfare.

The argument for harmonization upward, rather than downward, exists even in our static model. For stocks in region I, harmonization upward and downward are equivalent, but for stocks in region IV harmonization upward benefits South and has no effect on North, while harmonization downward harms North and has no effect on South. It may be impossible to be

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increases, and may decrease, the maximum amount of unemployment in both countries.

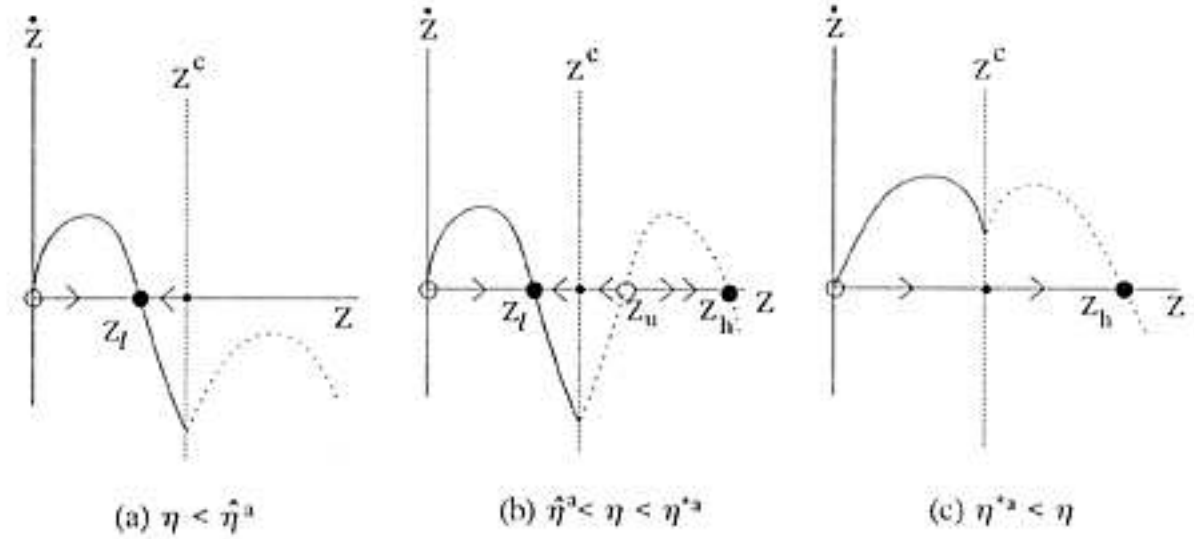
[8]However, absolute levels of the distortion do not effect the distribution of aggregate consumption.

certain whether world stocks are in regions I or IV. If there is a positive probability that stocks are in region IV, harmonization upward always increases expected world welfare by more than harmonization downward.[9]

4. Dynamic Effects of Policy Reform

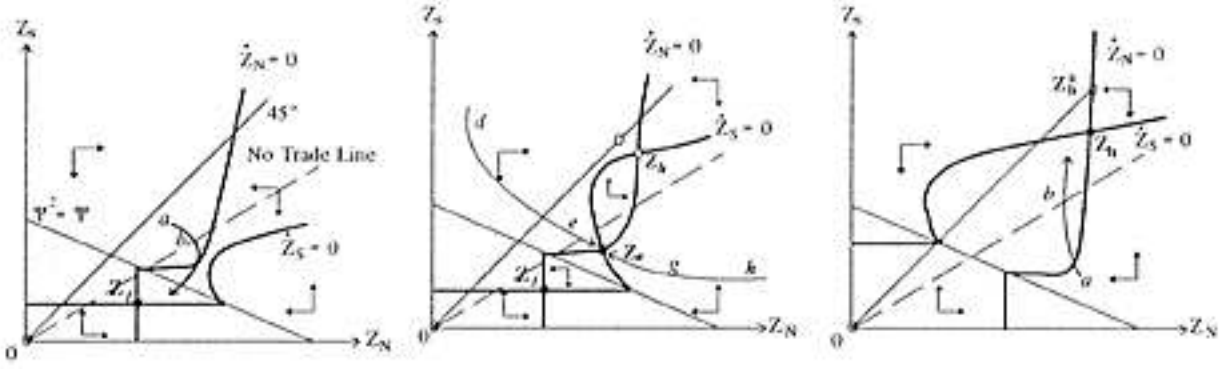
We now turn to a dynamic model, in order to study the effect of reform on environmental stocks, and thus on long-run welfare. We use the logistic growth function for the stock: $dZ_i/dt \equiv \dot{Z}_i = \eta Z_i - \gamma Z - E_i$. The parameter γ measures the congestion effect in growth; η is the non-congested growth rate of the environment, and thus gives a measure of environmental resilience. As we previously discussed, in autarky the equilibrium E_i is an increasing function of $\delta_i Z_i$ for $Z_i < Z(\delta_i)$ and constant for $Z_i > Z(\delta_i)$. With free trade, the equilibrium E_i is an increasing function of $\delta_i Z_i$ for $\psi < \psi^c$ and an increasing function of $\delta_i Z_i/(\delta_i Z_i + \delta_j Z_j)$ for $\psi > \psi^c$. Under both autarky and free trade there are two dynamic regimes, depending on whether labor is fully employed.

[9] Harmonization upward may be more difficult and expensive than harmonization downward. For example, there may more opposition to improving standards in South than to downgrading them in North. If a supranational organization, whose goal is to increase *instantaneous* welfare, is certain that stocks are in region I, the correct policy is to harmonize downward. However, if the stock level is uncertain, with a positive probability that it is in region IV, the correct policy might be harmonization upward, despite its greater cost.



(a) $\eta < \hat{\eta}^a$ (b) $\hat{\eta}^a < \eta < \eta^{*a}$ (c) $\eta^{*a} < \eta$

Figure 6: Autarkic Dynamics for Different η



(a) $\eta < \hat{\eta}$ (b) $\hat{\eta} < \eta < \eta^*$ (c) $\eta > \eta^*$

Figure 7: Free Trade Dynamics for Different η

Figures 6 and 7 show three possible dynamic portraits for autarky and trade. Figure 6 shows the graphs ofZ under autarky. We use dashed and solid curves for values of Z above and below Z^c, for ease of reference later. Figure 7 shows the phase portraits under free trade. The qualitative dynamics, under both trade and autarky, depend on the magnitude of η. There are four critical values of this parameter, ^{a} and η^{*a} for autarky, and and η^* for free trade. Under autarky, for $\eta < {}^a$ there is a unique low stable steady state with unemployed labor, Z_l; for $^a < \eta < \eta^{a*}$ there is a low stable steady state with unemployed labor, a high stable steady state with full employment (Z_h), and an intermediate unstable steady state (Z_u); for $\eta^{*a} < \eta$ there is a unique high stable steady state with full employment. The three cases under free trade are similar, although the critical values of η are different. The low stable steady state under trade, $\mathbf{Z_l}$ has unemployment in both countries, and the high stable steady state, $\mathbf{Z_h}$, has full employment. The unstable steady state is $\mathbf{Z_u}$.

We study the dynamic effect of reform by examining the steady state effect of a non-marginal decrease in δ_i. A marginal change in δ_i could cause a non-marginal change in steady state only for "knife-edge" cases, where η or the initial value of Z was at a critical level. We are able to study the effect of non-marginal changes using comparative statics because the important endogenous functions are monotonic in δ. When we say that reform has a "qualitative effect" we mean that it has the potential to change the characteristics of the stock dynamics: for example, reform might change the dynamic representation from Figure 6a to 6b (or from 7a to 7b). In order for a qualitative change to occur, reform must change the critical values ^{a} () and/or η^{a*} (η^*) by a large enough amount that their position relative to the fixed value of η changes. When we say that reform has only a "quantitative effect" we mean that it alters the position of steady states, but does not change the representation of stock dynamics. In this case, reform does not change the critical values of η by enough to alter their position relative to η, the non-congested growth rate of the environment.

4.1. Dynamic Effects of Reform under Autarky

The dynamic effect of reform in autarky is straightforward. The comparative statics are

Install Equation Editor and double-click here to view equation. **(1)**

The geometric proof of equation (1) is based on the facts that$Z$ is independent of δ for $Z > Z^c$ and$Z$ is decreasing in δ for $Z < Z^c$ (see Section 2.2). In terms of figure 6, the positions of the dashed curves are independent of δ, and the solid curves are lower for higher δ. To verify (1a), suppose that $\eta = {}^a$, so that the dashed curve is tangent to the horizontal axis. Since a change in δ does not alter the position of this curve, there remains a single (low) steady state (even after δ has changed), which implies (1a). To verify (1b), suppose that $\eta = \eta^{*a}$, so that the two curves in figure 6 intersect on the horizontal axis (at Z^c). Since an increase in δ shifts down the solid curve without altering the position of the dashed curve, the curves must now intersect below the horizontal axis. Hence, there are two stable steady states, so after the increase in δ, η lies below the critical η^{*a}, implying equation (1b). Equation (1c) is obvious: a worse environmental distortion makes it more likely that labor will be fully employed for given Z, and thus decreases Z^c. To show this geometrically, we use the fact that an increase in δ shifts down the solid curves in figure 6, decreasing the point where the solid and dashed curves intersect. This intersection determines Z^c. The location of the unstable and high steady states (if they exist) are determined by the intersection(s) of the dashed curve with the Z axis. The dashed curve, and therefore the points of intersection, are independent of δ. The location of the low steady state (if it exists) is given by the intersection of the Z axis and the solid curve in Figure 6, which does depend on δ. We verify (1f) in Appendix B.2.

Equation (1) has several implications for environmental reform under autarky. We noted in Section 3 that for $Z < Z^c$, reform increases instantaneous welfare and unemployment and

decreases the flow of environmental extraction. In the short run, then, environmental and welfare objectives conflict with employment objectives. From (1f), in the long run these goals are compatible, even if the economy reaches a low steady state with unemployment. In the long run, environmental reform allows the environment to improve sufficiently that employment is higher despite tighter regulations. Whether a government wants to undertake reform depends on its short-run tradeoff between national welfare (and the environment) and employment, and also on its discount rate.

Reform can also cause qualitative dynamic changes. There are three cases.

Case I: If $\eta < {}^{a}$, decreasing δ has no qualitative effect. The economy always reaches a low steady state with unemployment. Reform has only the quantitative effects described in the previous paragraph, for $Z < Z^{c}$.

Case II: If $\eta > \eta^{*a}$, reform has neither a (long run) qualitative nor a quantitative effect. The only effect of reform is that for $Z < Z^{c}$, both unemployment and welfare are higher, and the environment improves more rapidly.

Case III: For the intermediate case, ${}^{a} < \eta < \eta^{*a}$, the magnitude of the reform is important. If the reform is "moderate", in the sense that figure (6b) continues to represent the dynamics, then the effect of reform depends on the initial condition, Z_o. When $Z_o < Z_u$ (which is independent of δ), reform has the quantitative effect described in Case I. When $Z_o > Z_u$, reform has no effect, as in Case II (with $Z_o > Z^{c}$). If the reform is sufficiently large, the post-reform dynamics are described by figure 6c. In that situation, reform causes a qualitative change even for small initial stocks, Z_o, since the stock approaches a high rather than a low level. For large initial stocks, a large reform has neither a quantitative nor a qualitative effect.

We summarize these conclusions in:

Remark 2. *(i) Under autarky, a non-infinitesimal reduction of* δ *can result in a qualitative change in the dynamics only if* Z_o *is small and the growth parameter, prior to reform, satisfies* ${}^{a} < \eta < \eta^{*a}$. *(ii) Reform can either increase or eliminate the low steady state, thereby decreasing or eliminating unemployment and improving welfare in the steady state. (iii) Reform has no*

effect on a full-employment steady state. ●

4.2. Dynamic Effects of Reform Under Free Trade

We now consider the long run effect of reform in the free-trade equilibrium. A reduction in δ_i has the same effect on the low steady state $\mathbf{Z_l} \equiv (Z_{Nl}, Z_{Sl})$ as under autarky: Z_{il} and $\delta_{il}Z_i$ increase, and Z_{jl}, $j \neq i$, is unchanged. A reduction in δ_i has indeterminate effects on the high steady state $\mathbf{Z_h} \equiv (Z_{Nh}, Z_{Sh})$. The only possibility that we can exclude is that reform in North decreases Z_{Nh} and increases Z_{Sh}. We expect that in the "usual case", Northern reform would increase Z_{Nh} and reduce Z_{Sh}, as production of E shifts to South. However, since a reduction in δ_N causes both isoclines in Figure 7 to shift down (for $\psi > \psi^C$), we can not rule out other possibilities.

The qualitative changes in the phase portrait are more interesting. Harmonization reduces the critical value of (appendix B.3), i.e.:

Install Equation Editor and double-click here to view equation. **2**

The critical value depends only on relative property rights or relative distortions, measured by δ_S/δ_N. Harmonization of policies, achieved by either an improvement in Southern standards, or an equal-proportionate deterioration in Northern standards, reduces δ_S/δ_N. If $\eta < (\delta_S/\delta_N)$ prior to harmonization, the unique steady state is $\mathbf{Z_l}$, where the environmental stock is low and there is unemployment. Harmonization may cause η to exceed the post-reform critical , so that after reform there also exists a high steady state. (The phase portrait changes from figure 7a to 7b.) If the initial stocks, $\mathbf{Z_o}$, are sufficiently large, harmonization causes the economies to move toward the high steady state. In this case, harmonization benefits both North and South in the long run, even if either of them suffers instantaneous welfare losses (Remark 1).

Conversely, unilateral reform in North, which represents a movement away from harmonization, could cause η to fall below . Suppose, for example, that pre-reform $\eta >$ and $\mathbf{Z_o}$ lies above the convergent saddle path through $\mathbf{Z_u}$, so that the economy is moving toward $\mathbf{Z_h}$. If after (Northern) reform, $\eta <$, the economy approaches the low steady state $\mathbf{Z_l}$. In this case, even

if North and/or South benefit from Northern reform in the short run, both lose in the long run.

Suppose now that the initial condition satisfies $\psi_o < \psi^c$ (low environmental stocks). Economies remain trapped at a low steady state even if harmonization changes the dynamics from Figure 7a to 7b. Any initial condition $\mathbf{Z_o}$ that satisfies $\psi_o < \psi^c$ necessarily lies below the convergent saddle path through the unstable steady state (see Figure 7b). Equilibrium trajectories for initial conditions $\psi_o < \psi^c$ converge to the low steady state. The fact that the high steady state comes into existence is irrelevant (for sufficiently low internal conditions). Reform in either country increases its apparent and real environmental stock in the long run and thus increases that country's steady state welfare, without altering the other country's steady state.

The critical value η^*, above which only a high steady state exists, depends on both the relative and absolute values of δ_i; we saw that the critical value of depends only on relative values. Reform in South (a reduction in δ_S) decreases both the absolute distortion in South and its distortion relative to North. Consequently, $d\eta^*/d\delta_S < 0$ (appendix B.4). Southern reform may cause the phase portrait to change from figure 7b to 7c. In that case, if the economies were trapped at a low steady state, reform would cause them to move to a high steady state with full employment.

Northern reform increases the relative distortions but decreases an absolute distortion. The effect of Northern reform on η^* depends on which of those influences is stronger. This comparison depends on the severity of the environmental problem and the initial difference between δ_S and δ_N. We define the index $g \equiv \gamma a_2 \psi^c$, as a measure of the severity of the environmental problem. This index depends on the physical/biological process, and on the economic variables which describe production and preferences, but not on δ_i. The index is an increasing function of the congestion parameter γ. Greater congestion tends to make the environmental problem more severe. The parameter a_2, defined in Appendix A, is the amount of the environmental factor needed to produce a unit of commodity B. An increase in a_2 means that the environment becomes more important to production, and low environmental stocks become more damaging. Finally, ψ^c, which is a function of all of the economic parameters except δ_i, is the

minimum aggregate apparent stock needed for full employment. An increase in ψ^c also means that the environment, and thus environmental problems, are more important.

The effect on η^* of δ_N depends on whether the index g exceeds a critical level, defined as $g^* \equiv \delta + 2\delta_N - 1$, and on whether δ_S exceeds a critical value δ^*, with $\delta_N < \delta^* < 1$ (Appendix B.4):

Install Equation Editor and double-click here to view equation. **3**

Equation (3) states that if the environmental problem is not "very severe" ($g < g^*$), then the absolute effect of Northern reform always dominates the relative effect, and Northern reform decreases the critical value η^*. If, on the other hand, the environmental problem is "very severe" ($g > g^*$), then either the absolute or relative effect may dominate. If the difference between the economies is large ($\delta_S > \delta^*$), the relative effect dominates, and Northern reform increases the critical value of η^*.[10] If the difference between the economies is small ($\delta_S < \delta^*$), the absolute effect dominates, and Northern reform decreases the critical value of η^*. The fact that upward harmonization certainly decreases η^*, but downward harmonization may increase η^*, creates a strong presumption in favor of upward rather than downward harmonization.

Remark 3 summarizes the implications of equations (2) and (3). When we say that an outcome is "less likely", we mean that the range of parameter values for which the result occurs is reduced.

Remark 3. *(i) Southern reform, i.e., a movement toward harmonization of environmental policies, decreases both the critical values and* η^*. *Reducing these values makes it less likely that there will be a unique low steady state (Fig 7a represents the dynamics), and more likely that there will be a unique high steady state (Fig 7c). (ii) If, prior to reform, both a low and high*

[10] Since g^* is increasing in δ_N, for larger Northern distortions it is less likely that $g > g^*$, and therefore less likely that $d\eta^*/d\delta_N < 0$.

steady state exist (Fig 7b), then the high steady state may vanish after Northern reform, causing the economies to approach the low steady state (Fig 7a). (iii) When both steady states initially exist, Northern reform may eliminate the low steady state (Figure 7c), providing that: (a) the environmental problem is not too severe or (b) the initial difference between North and South is not too great. If neither of these conditions hold, and if initially only a high steady state exists (Figure 7c), then Northern reform can cause a low steady state to exist (as in Figures 7a and 7b).

●

4.3. Discussion of Results

Comparison of Remarks 3 and 1 shows how the dynamic and static effects of reform differ under free trade. In region I, where "trade matters", instantaneous aggregate welfare depends only on the relative distortions. Harmonization, whether achieved by upgrading Southern standards or degrading Northern standards, has the same aggregate instantaneous effect. Upgrading Southern standards is a better option only if the level of environmental stocks is uncertain, with a positive probability that stocks are in region IV, where trade does not matter.

For the dynamic analysis, on the other hand, absolute as well as relative levels of standards are important. Consideration of long run effects creates an additional reason for preferring upward rather than downward harmonization. In the long run, reform affects environmental stocks, which may be of more concern to environmentalists than standard welfare measures. Harmonization upwards is more likely than harmonization downwards to cause a qualitative improvement in environmental dynamics and an increase in long run stocks.

Comparison of Remarks 3 and 2 shows how the dynamic effects of reform depend on the trade regime. In a closed economy, reform does not alter the critical value ^{a}, below which only a low steady state exists. Therefore, if a country under autarky is trapped in a steady state with low environmental stocks and unemployment, even substantial environmental reform cannot lead to a qualitative improvement (high stocks and full employment). In contrast, if open economies are trapped in a low steady state with unemployment, harmonization of environmental policies can enable them to escape to a full-employment high steady state. Harmonization requires either

reform in the country with lower standards or a relaxation of policies in the country with higher standards.

In a closed economy, reform always reduces the critical value , above which only a high steady state exists. Therefore, if an autarkic economy has both the danger of going to a low steady state and the possibility of reaching a high steady state, reform can ensure that the economy reaches the high steady state. With open economies, reform in the more distorted economy reduces η^*; reform in the less distorted economy may increase this critical value. Therefore, in open economies, reform in the less distorted economy can either increase or decrease the danger that environmental stocks move to a low steady state.

Finally, the three Remarks show that environmental reform has different short and long run effects on unemployment. Under both free trade and autarky, environmental reform always increases unemployment in the short run, when this is initially positive. In the long run, however, the environmental and employment goals are compatible. When unemployment is positive in the steady state, under either trade or autarky, environmental reform either decreases or eliminates it.

5. Conclusion

We used a simple general equilibrium model to compare the short and long run effects of environmental reform in open and closed economies. Our chief point is that in open economies, relative distortions, in addition to absolute distortions, are important. When stated so baldly, this seems like an obvious conclusion, but it is at odds with the conventional wisdom both of economists and environmentalists.

Economists usually argue against harmonization of environmental policies for local pollution problems. The basis for this position is the belief that differences in policies reflect differences in tastes, technology, or endowments. Harmonization stifles the expression of these differences and thus reduces efficiency. This argument against harmonization disappears if policy differences are caused by cross-country differences in market failures.

Our reasons for supporting harmonization of environmental policies are not likely to find

much favor with environmentalists. In the short run harmonization is important, but it may not matter a great deal if this is achieved by relaxing or tightening environmental policies. Harmonization decreases the discrepancy between real and apparent comparative advantage. To the extent that trade is driven by differences in environmental standards, and thus by apparent as opposed to real comparative advantage, harmonization can improve welfare even if it involves lowering standards in one country. The concern about the "race to the bottom" may therefore be exaggerated.

Our dynamic analysis provides an important reason for preferring upward to downward harmonization. Non-negligible changes in policies can have dramatic effects in economies with multiple equilibria. Upward harmonization increases the chance of arriving at a high steady state. Downward harmonization, despite the fact that it may have identical instantaneous (aggregate) effects, can reduce the chance of arriving at a high steady state. In the long run, absolute as well as relative levels matter, and as environmentalists claim, upward harmonization is generally better than downward harmonization.

Increasingly open markets requires that environmentalists adopt a global perspective, even for local pollution problems. It is important to weigh the benefits of investing resources to promote reform in different countries. Even when absolute levels of distortions are more important than relative levels, so that reform anywhere improves welfare, it is still likely that reform in the most highly distorted economies will produce larger benefits. Reform in those countries decreases both absolute distortions and differences in distortions. This conclusion has an tinge of "environmental imperialism". Developing countries sometimes advise environmentalists to put their own house in order before attempting to export environmental reform. This is bad advice, especially from the standpoint of developing nations likely to have relatively serious environmental distortions.

We also used our model to describe the tension between the goals of decreasing unemployment and of improving welfare and the environment. As "jobs first" activists claim, raising environmental standards increases unemployment, when unemployment is initially positive.

However, as environmentalists claim, in the long run improving environmental standards increases employment. Thus, it would be more accurate to describe the anti-environmentalist camp as "jobs *now* first".

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