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From Autarky to Free Trade: The Impact on Environment *

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Abstract

We consider a model with two countries, two commodities and production factors, labor and environment. The countries first choose their environmental standards and then the equilibrium market allocations are determined. We study a subgame perfect Nash equilibrium of this game for two types of environmental problems: *regional* and *international*.

We examine effects resulting from the transition from autarky to free trade and show that regulating interference with supply and demand may have a positive effect on environmental standards. In particular, a transfer of commodity from one country to the other can increase welfare and raise environmental standards in both countries.

Keywords: Free Trade, Autarky, Environmental Standards, International and Regional Environmental Problems.

1 Introduction

The integration of environmental objectives into economic policy typically introduces strategic interactions due to the public goods character of the environmental commodities, and due to the fact that environmental regulations are usually expected to affect the competitiveness of the national economy. Ulph (1996) focuses on "eco–dumping" in a setup with both governments and producers acting strategically. Among other things, the paper shows that welfare will be lower when both governments and producers act in this way. Similarly, Batabyal (1998) considers the problem whether an environmental policy in the context of a Cournot game can make a country worse off when the incidence of pollution is local. Moreover, the effects of environmental regulation by alternate instruments are of interest in the case of border-crossing pollution. Ono (1998) extends the standard model of public goods provision by considering consumption externalities arising from economic activities, which pollute the environment. Under certain assumptions in a strategic context income transfers in both directions can improve the global environmental quality. Finally, an additional source of strategic interactions is provided by an internationally operating oligopolistic industry, which reacts on the environmental policy of the government. Within a framework of intra-industry trade and, alternatively, competition on a third-country market, Conrad (1994) investigates optimal environmental taxes and subsidies for duopolistic firms located in two countries. Barrett (1994), on the other hand, analyses competitiveness for alternative market structures and alternative forms of industry competition. Under certain conditions, governments then have an incentive to impose "weak" environmental standards.

In contrast to the existing literature, our paper then focuses more on the transition from autarky to free trade in terms of the equilibrium structure, for both regional and international environmental problems. Interesting aspects in this context cover questions of a "level playing field", of "harmonization", as a basis for free trade, or of a "race towards the bottom" resulting from lax environmental standards, of "losing one's higher standards" due to international competition, and of an "immiserization" following an expected degradation of the environment in inter-

national trade. Bhagwati (1996) considers these problems to be the "genuine" ones in the context of free trade and the environment. In a more theoretical context, these problems are intimately associated with economic efficiency and fairness.

We consider a model with two countries each of which can produce two commodities by employing two factors of production, labor and environment. We assume that the production functions exhibit constant returns to scale with respect to labor input. A higher level of the environmental standard adopted in a country will decrease the output levels associated with a given labor input. We also assume that in each country there is a representative consumer, whose utility is given by a homothetic utility function. We examine two cases of environmental interdependence between the two countries. One is the class of *international* environmental problems, where environmental conditions in each country are affected by environmental standards chosen by the other country. Another is *regional* environmental problems, where none of the countries is affected by the other country's environmental problems. In contrast to international environmental problems, regional environmental problems do not directly affect production and utility in the other country.

The choice of an appropriate environmental standard is the task of governmental agencies, who, at the first stage of the game, propose the environmental standards in accordance with the welfare of the consumers while taking into account the respective action of the other country. In the second stage, the two commodities are produced and exchanged in each country according to the rules of a market economy. Our goal is to examine a subgame perfect Nash equilibrium of this game, that results from the interaction of governmental agencies in the two countries.

We show, in particular, that in equilibrium welfare of both countries may decrease when switching from autarky to free trade. Interestingly, this may occur not because of insufficient environmental protection, as is usually argued by environmentally active groups, but because of too much concern for the environment. "Immiserization" can happen, but for reasons different than usually expected.

We also address the issue whether regulating interference with supply and demand can have a positive effect on welfare. In particular, is it possible to stimulate the protection of the environment by unilateral measures such as taxes or subsidies,

quota or tariffs, lump-sum payments or transfers. What will happen to welfare in the country enacting a particular measure? What will happen to welfare in the country affected by this measure? We show that, somewhat counter intuitively, the introduction of a tariff does not affect equilibrium values of the environmental standards, although the change in international prices due to the tariff will have a positive effect on the welfare of the country imposing the tariff. In contrast, the transfer of some units of one of the consumption commodities will increase welfare in both countries, and we will also observe a raise of the levels of environmental standards.

The paper is organized as follows: The next section contains the basic assumptions of the model. In Section 3 we examine an autarky variant of the model. In Section 4 we turn to analysis of free trade. In Section 5 we compare the autarky and free trade equilibria. Section 6 investigates effects of regulatory interference. Some final remarks conclude the paper.

2 The Model

There are two countries $i, j = 1, 2$, each of which can produce two commodities by employing two factors of production, labor and environment. The production functions f_{ij} in country i, exhibit constant returns to scale with respect to commodity j:

$$f_{ij}(e_i, z_{ij}) = \beta_{ij}(1 - e_i)z_{ij} \text{ for } i, j = 1, 2 \text{ and } z_{ij} \leq Z_i,$$

where e_i, $0 \leq e_i \leq 1$, denotes the level of the environmental standard adopted in country i. We do not introduce here specific features of this standard, but one could think, for example, of e_i as an abatement level of hazardous waste adopted in country i. The quantity Z_i denotes the total labor endowment in country $i = 1, 2$. To simplify the matters, we assume that country 1 possesses a comparative advantage in the production of commodity 1, i.e.,

$$\frac{\beta_{11}}{\beta_{12}} > \frac{\beta_{21}}{\beta_{22}}.$$

Comparative cost advantages resulting from differences in technologies, factor endowments and market demand generate gains from free trade, and we do not consider economies of scale or imperfect competition as alternative sources of gains from trade.

Consumers in each country are characterized by an identical homothetic utility function. That is, there is a representative consumer in country i whose utility is given by:

$$u_i(x_{i1}, x_{i2}, E_i) = x_{i1}^{\alpha_{i1}} \cdot x_{i2}^{\alpha_{i2}} \cdot E_i^{\alpha_{i3}} \tag{1}$$

with $\alpha_{ij} > 0$ and $\alpha_{i1} + \alpha_{i2} = 1$ for $i, j = 1, 2$. The parameter α_{ij} denotes the share of total income of consumer i spent on commodity j, whereas α_{i3} is the "propensity" of consumer i towards the protection of the environment, and E_i is the state of environment in country i.

To specify the way E_i is evaluated, we consider two cases of environmental interdependence between the two countries. One is the class of *international* environmental problems, where environmental conditions in each country are affected by environmental standards chosen by the other country. In this case, the value of E_i is assumed to correspond to a weighted sum of the two environmental standards e_1 and e_2. That is, $E_i = \gamma_i e_i + (1 - \gamma_i) e_j$, $j \neq i$, where γ_i with $0 \leq \gamma_i \leq 1$ is an "impact factor" determined by climatic or other non-economic circumstances. It specifies the effect of country i's own environmental standard on its environmental conditions. Although it would affect most of our result we assume that both coefficients, γ_1 and γ_2 are not smaller than 0.5. In other words, an impact of its own standard on the state of environment in country i would be at least as strong as the standard chosen by the other country.

In the case of *regional* environmental problems, where none of the countries is affected by the other country's environmental problems and the choice of an environmental standard, E_i is simply equal to e_i, the value of the environmental standard adopted by country i. Obviously, by setting $\gamma_1 = \gamma_2 = 1$, we may consider the case of regional environmental problems as a special case of international environmental problems. It is, however, of interest to examine the case of regional environmental

effects separately. To distinguish between these two cases, we assume that in the case of international environmental problems, the coefficients γ_1 and γ_2 are strictly less than one, i.e., a choice of environmental standards in country j has a nonnegligible impact on the state of environment in country $i \neq j$.

The two commodities are produced and exchanged in each country according to the rules and regulations of a market economy. The choice of an appropriate environmental standard is, however, the task of governmental agencies. They propose the environmental standards in accordance with the welfare of the consumers while taking into account the respective action of the other country. Formally, we examine a two-stage model. In the first stage the governmental agencies choose their own environmental standards and in the second, firms and households make their production and consumption decisions by selecting equilibrium allocations in the goods and factor markets, given the choice of environmental standards in the first stage. Then we investigate a subgame-perfect Nash equilibrium of this game which is a natural concept to examine the outcome of the interaction of the governmental agencies in the two countries. Our assumptions guarantee that, given any pair of equilibrium standards chosen in the first stage, the choices of both countries in the second stage are uniquely determined. Thus, by substituting the outcome of the second stage into countries' utilities, we may reduce our game to a one-stage game of environmental standards and to focus on its Nash equilibria.

In this paper we distinguish between *autarky*, where the countries are not engaged in commodity trade, and *free trade*. It gives rise to four different situations, which will be studied in the following sections:

- **autarky with regional environmental problems**,
- **autarky with international environmental problems**,
- **free trade with regional environmental problems**,
- **free trade with international environmental problems**.

3 Autarky Equilibrium

Consider first the autarky case in which there is no commodity trade between the two countries. Let (e_1, e_2), a pair of environmental standards, chosen in the first stage of the game, be given. Our assumptions guarantee that in the second stage there is a unique equilibrium allocation $(x_{ij}^A(e_i), z_{ij}^A(e_i))_{i,j=1,2}$ for which there exists a price system $(w_i^A(e_i), p_{i1}^A(e_i), p_{i2}^A(e_i))$ such that for $i, j = 1, 2$

- $x_{ij}^A(e_i) = f_{ij}(e_i, z_{ij}^A(e_i))$ for $i, j = 1, 2$,
- $z_{i1}^A(e_i) + z_{i2}^A(e_i) = Z_i$,
- $(z_{i1}^A(e_i), z_{i2}^A(e_i))$ is a profit-maximizing factor allocation in country i,
- the consumption bundle $(x_{i1}^A(e_i), x_{i2}^A(e_i))$ maximizes country i's utility given the budget $w_i^A(e_i) \cdot Z_i$.

Our specification of utilities yields:

$$x_{11}^A(e_1) = \alpha_{11}\beta_{11}(1-e_1)Z_1, \quad x_{12}^A(e_1) = \alpha_{12}\beta_{12}(1-e_1)Z_1,$$
$$x_{21}^A(e_2) = \alpha_{21}\beta_{21}(1-e_2)Z_2, \quad x_{22}^A(e_2) = \alpha_{22}\beta_{22}(1-e_2)Z_2.$$

By using these equilibrium allocations, we consider the indirect utilities of each country which depend only on the choices of e_1 and e_2.Thus, we reduce our game to the choice of environmental standards only.

In the case of international environmental problems we denote the indirect utilities by

$$v_i^{I,A}(e_1, e_2) = u_i(x_{i1}^A(e_i), x_{i2}^A(e_i), E_i) = u_i(x_{i1}^A(e_i), x_{i2}^A(e_i), \gamma_i e_i + (1-\gamma_i)e_j).$$

By using the utility specification (1) and the expressions for equilibrium allocations, we obtain:

$$v_1^{I,A}(e_1, e_2) = (\alpha_{11}\beta_{11})^{\alpha_{11}}(\alpha_{12}\beta_{12})^{\alpha_{12}}(1-e_1)Z_1(\gamma_1 e_1 + (1-\gamma_1)e_2)^{\alpha_{13}}, \quad (2)$$
$$v_2^{I,A}(e_1, e_2) = (\alpha_{21}\beta_{21})^{\alpha_{21}}(\alpha_{22}\beta_{22})^{\alpha_{22}}(1-e_2)Z_2(\gamma_2 e_2 + (1-\gamma_2)e_1)^{\alpha_{23}}. \quad (3)$$

For regional environmental problems we introduce the utility levels

$$v_i^{R,A}(e_1, e_2) = u_i(x_{i1}^A(e_i), x_{i2}^A(e_i), E_i) = u_i(x_{i1}^A(e_i), x_{i2}^A(e_i), e_i),$$

and, similarly to the case of international environmental problems, we have an explicit expression:

$$v_1^{R,A}(e_1) = (\alpha_{11}\beta_{11})^{\alpha_{11}}(\alpha_{12}\beta_{12})^{\alpha_{12}}(1-e_1)Z_1(e_1)^{\alpha_{13}}; \quad (4)$$

$$v_2^{R,A}(e_2) = (\alpha_{21}\beta_{21})^{\alpha_{21}}(\alpha_{22}\beta_{22})^{\alpha_{22}}(1-e_2)Z_2(e_2)^{\alpha_{23}}. \quad (5)$$

It is important to mention that the choice of an environmental standard e_i has an ambiguous effect on the utility of the consumers. On the one hand, there is a positive effect of a cleaner environment, whereas, on the other hand, there is a negative effect resulting from lower production and consumption levels. Moreover, in the case of international environmental effects the actions of the foreign government will affect the home country directly. We consider, therefore, a strategic interaction for the governmental agencies of the two countries, which is captured in the following definitions of an autarky equilibrium. It is simply a Nash equilibrium under autarky regime where strategic variables are represented by choices of environmental standards.

Definition 3.1 *The pair of environmental standards* $(e_1^{I,A}, e_2^{I,A})$ *is an* **autarky equilibrium with respect to international environmental problems** *if the inequality*

$$v_i^{I,A}(e_1^{I,A}, e_2^{I,A}) \geq v_i^{I,A}(e_i, e_j^{I,A})$$

holds for every level of environmental standard e_i, $0 \leq e_i \leq 1$.

Definition 3.2 *The pair of environmental standards* $(e_1^{R,A}, e_2^{R,A})$ *is an* **autarky equilibrium with respect to regional environmental problems** *if the inequality*

$$v_i^{R,A}(e_1^{R,A}, e_2^{R,A}) \geq v_i^{R,A}(e_i, e_j^{R,A}).$$

holds for every level of environmental standard e_i, $0 \leq e_i \leq 1$.

3.1 Autarky with International Environmental Problems

Our first result demonstrates the role of the propensities towards the protection of the environment, α_{13} and α_{23}, and the impact factors γ_1 and γ_2. The country with a higher "adjusted" propensity towards the protection of the environment will adopt a higher environmental standard:

Result 3.1.1 *Let a pair* $(e_1^{I,A}, e_2^{I,A})$ *be an equilibrium. Then the inequality* $e_1^{I,A} > e_2^{I,A}$ *holds if and only if* $\gamma_1\alpha_{13} > \gamma_2\alpha_{23}$.

Proof: Let a pair of the environmental standards (e_1, e_2) be given. The expressions in (2) and (3) allow us to derive the best response functions of each country, $e_1^{br}(e_2)$ and $e_2^{br}(e_1)$. For interior solutions we obtain:

$$e_1^{br}(e_2) = \frac{\gamma_1\alpha_{13} - (1-\gamma_1)e_2}{\gamma_1(1+\alpha_{13})};$$
$$e_2^{br}(1_2) = \frac{\gamma_2\alpha_{23} - (1-\gamma_2)e_1}{\gamma_2(1+\alpha_{23})}.$$

Then we obtain the following (interior) equilibrium values of the environmental standards:

$$e_1^{I,A} = \frac{\gamma_1\gamma_2(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23}) - \gamma_2\alpha_{23}}{\gamma_1\gamma_2(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23}) + (\gamma_1 + \gamma_2 - 1)}, \tag{6}$$
$$e_2^{I,A} = \frac{\gamma_1\gamma_2(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23}) - \gamma_1\alpha_{13}}{\gamma_1\gamma_2(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23}) + (\gamma_1 + \gamma_2 - 1)}. \tag{7}$$

It remains to observe that the only different terms in (6) and (7) are $\gamma_1\alpha_{13}$ and $\gamma_2\alpha_{23}$. Thus, $e_1^{I,A} > e_2^{I,A}$ if and only if $\gamma_1\alpha_{13} > \gamma_2\alpha_{23}$.□

An inspection of the above reaction curves reveals that both higher values of the impact factor γ_i and the coefficient α_{i3} will shift these curves outward and thus induce more concern for the protection of the environment.

Now let us turn to the issue of efficiency of the equilibrium. Our next result shows that, in general, the equilibrium levels of environmental standards in international setting are not efficient (see Figure 1). A unilateral increase in the environmental

standard in country 1 raises welfare of country 2 and a unilateral increase in the environmental standard in country 2 raises welfare of country 1. Then the convexity of the indifference curves yields the existence of the values e_1 and e_2 with $e_i > e_i^{I,A}$ for $i = 1, 2$ such that $v_i^{I,A}(e_1, e_2) > v_i^{I,A}(e_1^{I,A}, e_2^{I,A})$ for $i = 1, 2$. In this sense there is "too little" concern about the environment.

Several international agreements to protect the environment, e.g. the Kyoto Protocol, require a uniform percentage reduction of emission levels of some hazardous waste. In our framework this would correspond to a uniform percentage increase of the values of the environmental standards. It turns out that "small" uniform percentage increases in the environmental standards may, indeed, improve welfare in both countries:

Result 3.1.2 *The Nash equilibrium* $(e_1^{I,A}, e_2^{I,A})$ *is inefficient. Moreover, an improvement in the welfare of both countries can only be achieved by a simultaneous raise of their environmental standards. Furthermore, there exists a value* $t > 0$ *such that both countries will be better off by adopting the standards* $e_i = e_i^{I,A} + te_i^{I,A}$, $i = 1, 2$*, respectively, rather than the equilibrium standards.*

Proof: Expressions (2)-(3) imply that the welfare of country i is positively correlated with the level of environmental standards in country $j \neq i$. Thus the welfare improvement in both countries with respect to the Nash equilibrium is possible only if both countries raise their levels of standards.

Consider now the pair of equilibrium environmental standards $(e_1^{I,A}, e_2^{I,A})$. Recall that the first order conditions for country 1 yield

$$-\frac{1}{1 - e_1^{I,A}} + \frac{\gamma_1 \alpha_{13}}{\gamma_1 e_1^{I,A} + (1 - \gamma_1) e_2^{I,A}} = 0,$$

which can be rewritten as

$$\alpha_{13} = \frac{e_1^{I,A}}{1 - e_1^{I,A}} + \frac{(1 - \gamma_1) e_2^{I,A}}{\gamma_1 (1 - e_1^{I,A})}.$$

Suppose now that both countries jointly increase their environmental levels by the same percentage $t > 0$ and let us evaluate the change in countries' utilities. We have

$$\frac{d\{ln(v_1^{I,A}(e_1^{I,A}(1+t), e_2^{I,A}(1+t))\}}{dt}|_{t=0} = -\frac{e_1^{I,A}}{1-e_1^{I,A}} + \alpha_{13} = \frac{e_1^{I,A}}{1-e_1^{I,A}} + \frac{(1-\gamma_1)e_2^{I,A}}{\gamma_1(1-e_1^{I,A})}.$$

Since $\gamma_1 < 1$, the last expression is positive and both countries could be made better off by a certain uniform percentage raise of their environmental standards.□

Given this result on the inefficiency of the Nash equilibrium, harmonization of environmental standards may improve the welfare of both countries only if the "harmonized" values of the environmental standards are above the Nash equilibrium levels (Figure 2: Relative Changes). However, harmonization in the sense of *identical* values for the environmental standards across countries may work only for countries, which are not too far apart in terms of the equilibrium levels of the environmental standards in autarky. If the gap in the equilibrium standards is too wide, harmonization may not raise welfare in both countries simultaneously (Figure 2: Absolute Changes). This may explain the reason why some intermediate measures to increase the environmental "awareness" in poor and developing countries are necessary before any comprehensive international agreements on identical environmental standards are achieved.

3.2 Autarky with Regional Environmental Problems

In this case the value of the parameters γ_1 and γ_2 is equal to one and the countries are not affected by the choices of the environmental standards of their neighbors. Note that expressions (4)-(5) allow us to derive the following (interior) equilibrium values for the environmental standards:

$$e_1^{R,A} = \frac{\alpha_{13}}{1+\alpha_{13}}, \tag{8}$$

$$e_2^{R,A} = \frac{\alpha_{23}}{1+\alpha_{23}}. \tag{9}$$

The following corollary of Result 3.1.1 again demonstrates the role of the propensities towards the protection of the environment, α_{13} and α_{23}: the country with the

higher propensity towards the protection of the environment will adopt the higher environmental standard:

Result 3.2.1 *Let a pair* $(e_1^{R,A}, e_2^{R,A})$ *be an equilibrium. Then the inequality* $e_1^{R,A} > e_2^{R,A}$ *holds if and only if* $\alpha_{13} > \alpha_{23}$.

However, Result 3.1.1. on the inefficiency of equilibrium does no longer hold in the case of regional environmental problems. Indeed, under autarky there is no interaction between the two governments and each country independently makes its optimal choice:

Result 3.2.2 *The equilibrium* $(e_1^{R,A}, e_2^{R,A})$ *is efficient. Moreover, the equilibrium is the first best in the sense that* $v_i^{R,A}(e_1^{R,A}, e_2^{R,A}) \geq v_i^{R,A}(e_1, e_2)$ *for both countries and all levels of environmental standards* e_1 *and* e_2.

In this context there is no need to consider a harmonization of the equilibrium environmental standards. However, due to strategic interactions, the situation will change when we allow for free trade examined in the next section.

4 Free Trade Equilibrium

In the case of free trade, the environmental decisions of the governments will also be affected by the amount of commodities available for import or export.

Our assumptions guarantee that for every pair of environmental standards (e_1, e_2), there is a unique second-stage allocation $(x_{ij}^T(e_1, e_2), z_{ij}^T(e_1, e_2))_{j=1,2}$ with a price system $(w_i^T(e_1, e_2), p_1^T(e_1, e_2), p_2^T(e_1, e_2))_{i=1,2}$ such that for $i, j = 1, 2$

- $x_{1j}^T(e_1, e_2) + x_{2j}^T(e_1, e_2) = f_{1j}(e_1, z_{1j}^T(e_1, e_2)) + f_{2j}(e_2, z_{2j}^T(e_1, e_2))$,
- $z_{i1}^T(e_1, e_2) + z_{i2}^T(e_1, e_2) = Z_i$,
- $(z_{i1}^T(e_1, e_2), z_{i2}^T(e_1, e_2))$ is a profit-maximizing factor allocation in country i,
- the consumption bundle $(x_{i1}^T(e_1, e_2), x_{i2}^T(e_1, e_2))$ maximizes country i's utility given the budget $w_i^T(e_1, e_2) \cdot Z_i$.

Similar to the case of autarky, our specification of utilities implies that

$$x_{11}^T(e_1,e_2) = \alpha_{11}\beta_{11}(1-e_1)Z_1, \;\; x_{12}^T(e_1,e_2) = \alpha_{21}\beta_{22}(1-e_2)Z_2,$$
$$x_{21}^T(e_1,e_2) = \alpha_{12}\beta_{11}(1-e_1)Z_1, \;\; x_{22}^T(e_1,e_2) = \alpha_{22}\beta_{22}(1-e_2)Z_2.$$

Observe, however, that due to international trade $x_{1j}^T(e_1,e_2)$ and $x_{2j}^T(e_1,e_2)$ add up to $\beta_{jj}(1-e_j)Z_j$, the total amount of commodity j, to be produced in country j with complete specialization resulting from free trade.

Let $i,j = 1,2$ with $i \neq j$. In the case of international environmental problems denote

$$v_i^{I,T}(e_1,e_2) = u_i(x_{i1}^T(e_1,e_2), x_{i2}^T(e_1,e_2), \gamma_i e_i + (1-\gamma_i)e_j),$$

By using (1) and the expressions for equilibrium allocations, we can derive the utility levels in both countries for any pair of environmental standards (e_1,e_2):

$$v_1^{I,T}(e_1,e_2) = (\alpha_{11}\beta_{11}(1-e_1)Z_1)^{\alpha_{11}}(\alpha_{21}\beta_{22}(1-e_2)Z_2)^{\alpha_{12}}(\gamma_1 e_1 + (1-\gamma_1)e_2)^{\alpha_{13}}, \quad (10)$$
$$v_2^{I,T}(e_1,e_2) = (\alpha_{12}\beta_{11}(1-e_1)Z_1)^{\alpha_{21}}(\alpha_{22}\beta_{22}(1-e_2)Z_2)^{\alpha_{22}}(\gamma_2 e_2 + (1-\gamma_2)e_1)^{\alpha_{23}}. \quad (11)$$

Similarly, in the case of regional environmental problems denote the indirect utilities

$$v_i^{R,T}(e_1,e_2) = u_i(x_{i1}^T(e_1,e_2), x_{i2}^T(e_1,e_2), e_i),$$

Again, using the specification of utilities and the expressions for equilibrium allocations, for a given pair of environmental standards (e_1,e_2), we obtain the following expressions for indirect utilities:

$$v_1^{R,T}(e_1,e_2) = (\alpha_{11}\beta_{11}(1-e_1)Z_1)^{\alpha_{11}}(\alpha_{21}\beta_{22}(1-e_2)Z_2)^{\alpha_{12}}(e_1)^{\alpha_{13}}, \quad (12)$$
$$v_2^{R,T}(e_1,e_2) = (\alpha_{12}\beta_{11}(1-e_1)Z_1)^{\alpha_{21}}(\alpha_{22}\beta_{22}(1-e_2)Z_2)^{\alpha_{22}}(e_2)^{\alpha_{23}}. \quad (13)$$

The ambiguous effect of choosing environmental standards is amplified by free trade. It is important to examine whether lax environmental standards will lead to a "race towards the bottom" and therefore to a possibly lower welfare or "immiserization". The governmental agencies of the two countries face the strategic dilemma, which is captured by the following definitions of free trade equilibria.

Definition 4.1 *The pair of environmental standards* $(e_1^{I,T}, e_2^{I,T})$ *is a* **free trade equilibrium with respect to international environmental problems** *if the following inequality*

$$v_i^{I,T}(e_1^{I,T}, e_2^{I,T}) \geq v_i^{I,T}(e_i, e_j^{I,T})$$

holds for every level of environmental standard e_i, $0 \leq e_i \leq 1$.

Definition 4.2 *The pair of environmental standards* $(e_1^{R,T}, e_2^{R,T})$ *is a* **free trade equilibrium with respect to regional environmental problems** *if the following inequality*

$$v_i^{R,T}(e_1^{R,T}, e_2^{R,T}) \geq v_i^{R,T}(e_i, e_j^{R,T})$$

holds for every level of environmental standard e_i, $0 \leq e_i \leq 1$.

4.1 Free Trade with International Environmental Problems

We assume again that country $i = 1, 2$ specializes completely in the production of commodity i when switching from autarky to free trade.

In determining the environmental standards, note that, as in the case of autarky, the propensity towards the protection of the environment still plays an important role in determining the equilibrium levels of the environmental standards. However, the governments are less willing to adopt higher standards with an increasing share of the consumers' expenditures on the "home" product. This problem does not arise in the case of autarky, characterized by incomplete specialization in the production of both commodities. Under free trade, it seems more important to protect consumers from a too extensive reduction in the production of the commodity due to a high environmental standard. Our result states that the country with a higher ratio of the propensity towards protection of environment and the share of income devoted to its "home" product will adopt a higher environmental standard:

Result 4.1.1 *The equilibrium environmental standard is higher in country 1 than in country 2 if and only if* $\gamma_1\alpha_{13}/\alpha_{11} > \gamma_2\alpha_{23}/\alpha_{22}$.

Proof: By using (10)-(11), we find can the values of the environmental standards associated with an interior free trade equilibrium:

$$e_1^{I,T} = \frac{\gamma_1\gamma_2(\alpha_{13}\alpha_{22} + \alpha_{13}\alpha_{23} + \alpha_{11}\alpha_{23}) - \gamma_2\alpha_{11}\alpha_{23}}{\gamma_1\gamma_2(\alpha_{13}\alpha_{22} + \alpha_{13}\alpha_{23} + \alpha_{11}\alpha_{23}) + (\gamma_1 + \gamma_2 - 1)\alpha_{11}\alpha_{22}}, \tag{14}$$

$$e_2^{I,T} = \frac{\gamma_1\gamma_2(\alpha_{13}\alpha_{22} + \alpha_{13}\alpha_{23} + \alpha_{11}\alpha_{23}) - \gamma_1\alpha_{22}\alpha_{13}}{\gamma_1\gamma_2(\alpha_{13}\alpha_{22} + \alpha_{13}\alpha_{23} + \alpha_{11}\alpha_{23}) + (\gamma_1 + \gamma_2 - 1)\alpha_{11}\alpha_{22}}. \tag{15}$$

It remains to observe that the only difference between (14) and (15) is the expressions $\gamma_2\alpha_{11}\alpha_{23}$ and $\gamma_1\alpha_{22}\alpha_{13}$. Thus, $e_1^{I,T} > e_2^{I,T}$ if and only if $\gamma_1\alpha_{13}/\alpha_{11} > \gamma_2\alpha_{23}/\alpha_{22}$.□

In contrast to Result 3.1.1 for the autarky case, the values α_{ii}, $i = 1, 2$, of the propensities to consume its own product, play a role in this result. A smaller value of α_{ii} reduces the importance of commodity i, which is produced in country i under complete specialization in free trade. For this reason a smaller value of α_{ii} raises cet. par. the efforts to protect the environment in country i. Moreover, it can happen that $e_1^{I,T} > e_2^{I,T}$, although $\alpha_{13} < \alpha_{23}$. In this sense, the issue of an "unfair trade" because of different propensities towards the protection of the environment becomes blurred.

Let us now turn to the issue of efficiency (or rather inefficiency) of the Nash equilibrium in our framework. The inspection of the indirect utility functions reveals that an increase in the environmental standard e_j will either increase or decrease utility $v_i^{I,T}$, $i \neq j$. The exact direction of change depends, however, on the values of the parameters, as e_j affects $v_i^{I,T}$ in both a positive and a negative way. Hence, in equilibrium there could be too much or too little concern about the environment. There could even be the case that there is too much concern in one country and too little in the other one.

Result 4.1.2 *The Nash equilibrium* $(e_1^{I,T}, e_2^{I,T})$ *is, in general, inefficient. The nature of the inefficiency depends intrinsically on the values of the parameters of the model. In particular, for the "symmetric" case, where* $\gamma_1 = \gamma_2 = 0.5$, $\alpha_{11} = \alpha_{22}$, $\alpha_{12} = \alpha_{21}$, $\alpha_{13} = \alpha_{23}$,

- *there is too much concern about the environment if* $\alpha_{11} < 0.5$,

- *there is too little concern about the environment if* $\alpha_{11} > 0.5$*,*
- *the Nash equilibrium is efficient if* $\alpha_{11} = 0.5$*.*

Proof: Consider first a symmetric case. By maximizing the (identical) utilities of two countries in the case where $e_1 = e_2$, we conclude that the utilities of both countries are maximized when $e_1 = e_2 = \alpha_{13}/(1 + \alpha_{13})$. However, by (14)-(15), the equilibrium standards are given by $e_1^{I,T} = e_2^{I,T} = \alpha_{13}/(2\alpha_{11} + \alpha_{13})$. Thus,

- there is too much concern about the environment if $2\alpha_{11} < 1$,
- there is too little concern about the environment if $2\alpha_{11} > 1$,
- the Nash equilibrium is efficient if $2\alpha_{11} = 1$.

□

It is quite easy to demonstrate the inefficiency of a Nash equilibrium, as we have done in the autarky case, by simultaneously changing environmental standards in both countries in the same direction, i.e., either by increasing or decreasing those levels. It is worth to point out that it is possible to improve the welfare of *both* countries, by increasing the standard in one country and decreasing it in another country.

Result 4.1.3 *It is possible that a raise of the equilibrium value of* $e_1^{I,T}$ *and a simultaneous decline of the value of* $e_2^{I,T}$ *yield an increase in the utilities of both countries. Consider the following example:*

$$\gamma_1 = 0.5,\ \alpha_{11} = 0.60,\ \alpha_{12} = 0.40,\ \alpha_{13} = 0.70,\ \beta_{11} = 3,\ \beta_{12} = 1,\ Z_1 = 40;$$
$$\gamma_1 = 0.5,\ \alpha_{21} = 0.75,\ \alpha_{22} = 0.25,\ \alpha_{23} = 0.90,\ \beta_{21} = 1,\ \beta_{22} = 1,\ Z_2 = 50.$$

Assume that country 1 *increases its standard whereas country* 2 *decreases it at the same rate. We have*

$$\frac{d\{ln(v_1^{I,T}(e_1^{I,T}(1+t), e_2^{I,T}(1-t))\}}{dt}|_{t=0} =$$

$$= -\frac{\alpha_{11}e_1^{I,T}}{1-e_1^{I,T}} + \frac{\alpha_{12}e_2^{I,T}}{1-e_2^{I,T}} + \frac{\alpha_{13}(e_1^{I,T}-e_2^{I,T})}{(e_1^{I,T}+e_2^{I,T})} \approx 0.584 > 0,$$

$$\frac{d\{ln(v_2^{I,T}(e_1^{I,T}(1+t), e_2^{I,T}(1-t))\}}{dt}|_{t=0} =$$

$$= -\frac{\alpha_{21}e_1^{I,T}}{1-e_1^{I,T}} + \frac{\alpha_{22}e_2^{I,T}}{1-e_2^{I,T}} + \frac{\alpha_{23}(e_1^{I,T}-e_2^{I,T})}{(e_1^{I,T}+e_2^{I,T})} \approx 0.005 > 0.$$

Thus, a small increase in the value of $e_1^{I,T}$ and a small decrease in the value of $e_2^{I,T}$ will raise utilities in both countries (see Figure 3).

Harmonization in the sense of identical values of the environmental standards or in the sense of a uniform percentage adjustment of these values will therefore be sustainable only in exceptional situations. In view of the above observations, one of these exceptional cases is provided by countries with identical or almost identical consumers.

4.2 Free Trade with Regional Environmental Problems

The (interior) values of the environmental standards associated with free trade equilibrium are given by:

$$e_1^{R,T} = \frac{\alpha_{13}}{\alpha_{11}+\alpha_{13}}, \tag{16}$$

$$e_2^{R,T} = \frac{\alpha_{23}}{\alpha_{22}+\alpha_{23}}. \tag{17}$$

As in the case of international environmental problems, the propensity towards the protection of the environment plays an important role in determining the equilibrium levels of the environmental standards, and governments are less willing to adopt higher standards with an increasing share of the consumers' expenditures on the "home" product:

Result 4.2.1 *Let a pair $(e_1^{R,T}, e_2^{R,T})$ be an equilibrium. Then the inequality $e_1^{R,T} > e_2^{R,T}$ holds if and only if $\alpha_{13}/\alpha_{11} > \alpha_{23}/\alpha_{22}$.*

Proof: Follows immediately from (16)-(17).□

The inefficiency of the equilibrium arises from the fact that a unilateral decrease in the value of e_j raises indirect utility $v_i^{R,T}$ for $i \neq j$. The convexity of the indifference curves then implies that there exist values (e_1, e_2) with $e_i < e_i^{R,T}$ for $i = 1, 2$ such that $v_i^{R,T}(e_1, e_2) > v_i^{R,T}(e_1^{R,T}, e_2^{R,T})$ for $i = 1, 2$. Thus, there is "too much" concern about the environment. These conclusions are summarized in the following result:

Result 4.2.2 *The Nash equilibrium $(e_1^{R,T}, e_2^{R,T})$ is inefficient. Specifically, there is "too much" concern about the environment and an improvement in the welfare of both countries can only be achieved by a simultaneous decline of their environmental standards. Furthermore, there exists a value $t > 0$ such that both countries would be better off by adopting the standards $e_1 = (1-t)e_1^{I,A}$ and $e_2 = (1-t)e_2^{I,A}$ rather than the equilibrium standards.*

Proof: Expressions (12)-(13) imply that the welfare of country i is negatively correlated with the a level of environmental standards in country $j \neq i$. Thus, a welfare improvement in both countries is only possible if both countries choose lower levels of standards.

Consider now the pair of equilibrium environmental standards $(e_1^{R,T}, e_2^{R,T})$. The first order conditions for country 1 yield

$$-\frac{\alpha_{11}}{1 - e_1^{R,T}} + \frac{\alpha_{13}}{e_1^{R,T}} = 0. \tag{18}$$

Suppose now that both countries jointly change their environmental levels by the same percentage $t > 0$. Let us now examine the change in countries' utilities. We have

$$\frac{d\{ln(v_1^{R,T}(e_1^{R,T}(1+t), e_2^{R,T}(1+t))\}}{dt}|_{t=0} = -\frac{\alpha_{11}e_1^{R,T}}{1 - e_1^{R,T}} + \alpha_{13} - \frac{\alpha_{12}e_2^{R,T}}{1 - e_2^{R,T}}.$$

(18) implies that the last expression is negative. Thus, both countries could be made better off by a uniform percentage decrease of their environmental standards.□

As an immediate consequence, in the symmetric case $\alpha_{11} = \alpha_{22}$, $\alpha_{12} = \alpha_{21}$, $\alpha_{13} = \alpha_{23}$ both countries are better off by choosing a lower standard $e_1 = e_2 = \alpha_{13}/(1 + \alpha_{13})$ rather than $e_1^{R,T} = e_2^{R,T} = \alpha_{13}/(\alpha_{11} + \alpha_{13})$.

Given the result on the inefficiency of the Nash equilibrium, harmonized environmental standards can only be lower than the equilibrium values. This is, at first glance, a surprising result, closely related to the nature of the inefficiency. More exactly, a sufficiently small uniform percentage reduction of the values of the environmental standards will increase utilities of both countries in the framework considered here. Thus, a downward "harmonization" is sustainable in our framework.

However, "harmonized" equilibrium values in the sense of imposing identical environmental standards improving the situation of both countries exist only for countries, which are not too far apart in terms of the equilibrium levels of the environmental standards in free trade. The multiplicity of those harmonized standards poses another problem with respect to equilibrium selection (see Figure 4).

The next section contains a comparison of the autarky regime with free trade.

5 Comparison of Autarky with Free Trade

5.1 International Environmental Problems

The issues considered in this section are related to the possibility of a race towards the bottom and the immiserization in terms of an increasing degradation of the environment under free trade.

First we observe that even in the case of "symmetrical" environmental effects, one of the countries would decrease its environmental standard. However, it would not simultaneously happen for both countries:

Result 5.1.1 *Let $\gamma_1 = \gamma_2 = 0.5$. It is possible that the inequality $e_i^{I,A} > e_i^{I,T}$ is satisfied for country i. However, if $e_i^{I,A} > e_i^{I,T}$ then $E_j^A < E_j^T$ for $j \neq i$.*

Proof: By comparing the expressions in (6) and (14) we conclude that $e_1^{I,A} > e_1^{I,T}$ if and only if

$$\alpha_{22} + \alpha_{23} < \alpha_{11} + \alpha_{11}\alpha_{23}.$$

Similarly, a simple inspection of (7) and (15) yields that $e_2^{I,A} > e_2^{I,T}$ if and only if

$$\alpha_{11} + \alpha_{13} < \alpha_{22} + \alpha_{22}\alpha_{13}.$$

It is easy to see that the inequalities $e_1^{I,A} > e_1^{I,T}$ and $e_2^{I,A} > e_2^{I,T}$ cannot hold simultaneously. However, by choosing, for example, α_{22} and α_{23} relatively small to α_{11}, we can guarantee that $e_1^{I,A} > e_1^{I,T}$.□

But even more important question relates to the behavior of the proxy for the state of the environment in country i, $E_i = \gamma_i e_i + (1-\gamma_i)e_j$, when the country moves from autarky to free trade. Let us denote the state of environment of country i in autarky $E_i^A = \gamma_i e_i^{I,A} + (1-\gamma_i)e_j^{I,A}$, and under free trade $E_i^T = \gamma_i e_i^{I,T} + (1-\gamma_i)e_j^{I,T}$. We show that the first assertion of Result 5.1.1. does not any longer hold and in the case of symmetrical environmental effects, both values of the state of environment E_1 and E_2 would be higher under free trade than in autarky.

Result 5.1.2 *Let $\gamma_1 = \gamma_2 = 0.5$. Then $E_i^T > E_i^A$ for $i = 1, 2$.*

The proof of this result is presented in the Appendix.

However, if the symmetry of environmental effects is abandoned then it is possible that the state of environment in one country may decline. again, it cannot happen in both countries.

Result 5.1.3 *It is possible that the inequality $E_i^A > E_i^T$ is satisfied for country i. However, if it is indeed the case then $E_j^A < E_j^T$ for $j \neq i$.*

The proof of this result is relegated to appendix as well.

The final result of this subsection demonstrates that equilibrium utility levels in free trade problems may be below equilibrium utility levels in autarky when international problems are concerned. The reason for this "immiserization" is, however, not a degradation of the environment. To the contrary, immiserization arises from too much concern about the environment accompanied by an undue decrease of the production levels of the two commodities.

Result 5.1.4 *There exist values of the parameters such that* $v_1^{I,A} > v_1^{I,T}$ *and* $v_2^{I,A} > v_2^{I,T}$. *Consider the following example:*

$$\gamma_1 = 0.5\ \alpha_{11} = 0.05,\ \alpha_{12} = 0.95,\ \alpha_{13} = 0.5,\ \beta_{11} = 3,\ \beta_{12} = 1,\ Z_1 = 40;$$
$$\gamma_2\ \alpha_{21} = 0.90,\ \alpha_{22} = 0.10,\ \alpha_{23} = 0.5,\ \beta_{21} = 1,\ \beta_{22} = 1,\ Z_2 = 50.$$

By using the expressions (2)-(3) and (10)-(11), we have: $v_1^{I,A} \approx 17.532 > 14.999 \approx v_1^{I,T}$ *and* $v_2^{I,A} \approx 18.277 > 17.055 \approx v_2^{I,T}$.

5.2 Regional Environmental Problems

The first result shows that for the case of regional environmental problems a race towards the bottom in terms of an increasing degradation of the environment under free trade will not happen. The reason is the increase in world output, which is associated with free trade in comparison to autarky. Thus, there is "more room" for higher values of the environmental standards, and none of the countries must be concerned about losing "her higher standards".

Result 5.2.1 *The equilibrium levels of the environmental standards are always higher under free trade:* $e_i^{R,T} > e_i^{R,A}$ *for* $i = 1, 2$.

Proof: Follows from (8)-(9) and (16)-(17).□

Similar to the case of international environmental problems, by comparing the equilibrium levels of the environmental standards it is obvious that free trade levels may be different although the propensities towards the protection of the environment are identical across the countries. Thus, the issue of "unfair trade" cannot be justified alone on the basis of differing environmental standards in equilibrium.

The next result demonstrates that also in the case of regional environmental problems equilibrium utility levels in free trade may be below equilibrium utility levels in autarky. Again, the reason is not a worse state of the environment, but too much concern about the environment accompanied by an unwarranted decrease of the production levels of the two commodities.

Result 5.2.2 *There exist values of the parameters such that* $v_1^{R,A} > v_1^{R,T}$ *and* $v_2^{R,A} > v_2^{R,T}$. *An example is provided by*

$$\alpha_{11} = 0.05,\ \alpha_{12} = 0.95,\ \alpha_{13} = 0.5,\ \beta_{11} = 3,\ \beta_{12} = 1,\ Z_1 = 40;$$
$$\alpha_{21} = 0.90,\ \alpha_{22} = 0.10,\ \alpha_{23} = 0.5,\ \beta_{21} = 1,\ \beta_{22} = 2,\ Z_2 = 50.$$

By using the expressions (4)-(5) and (12)-(13), we obtain: $v_1^{R,A} \approx 13.337 > 12.118 \approx v_1^{R,T}$ *and* $v_2^{R,A} \approx 14.902 > 7.881 \approx v_2^{R,T}$.

We now turn to the issues associated with a regulatory interference with the equilibrium allocations.

6 Regulation

In the context of our results, one can ask whether regulating interference with supply and demand of the consumption commodities can have a positive effect on welfare. In particular, is it possible to stimulate the protection of the environment by unilateral measures such as taxes or subsidies, quota or tariffs, lump-sum payments or transfers? What will happen to welfare in the country enacting a particular measure? What will happen to welfare in the country affected by this measure?

6.1 Effects of a Tariff

We shall start our investigation with the effects of a simple proportional tax on the consumption of commodity 2 in country 1. Observe that because of complete specialization of country 1 in the production of commodity 1, this tax has all qualifications of a tariff on this commodity. Obviously this issue can be analyzed only in the framework of free trade. The analysis, however, covers both regional and international environmental effects.

Assume that $t > 0$ is a proportional tax on the consumption of commodity 2 in country 1. For fixed values of e_1 and e_2 we denote $Y_1(e_1) = \beta_{11}(1 - e_1)Z_1$ and $Y_2(e_2) = \beta_{22}(1 - e_2)Z_2$. We obtain the following conditions characterizing free trade

equilibrium in country 1 with equilibrium prices $p = (p_1, p_2)$:

$$p_1 x_{11} + p_2 x_{12} = p_1 Y_1(e_1)$$
$$\alpha_{12} p_1 x_{11} = \alpha_{11} p_2^t x_{12},$$

where $p_2^t = p_2(1+t)$ is the price paid by consumers and p_2 is the production price for commodity 2. (Note that tax revenue returned to the households in the form of a lump-sum payment.)

By solving these equations, we obtain the value of x_{12} that, obviously, depends on prices p:

$$x_{12} = \frac{p_1 \alpha_{12} Y_1(e_1)}{p_2(1+\alpha_{11} t)}.$$

Similarly, the equilibrium conditions for country 2 yield $x_{22} = \alpha_{22} Y_2(e_2)$.

Consequently, from $x_{12} + x_{22} = Y_2(e_2)$ we obtain the equilibrium prices

$$\frac{p_1}{p_2} = \frac{\alpha_{21}(1+\alpha_{11} t) Y_2(e_2)}{\alpha_{12} Y_1(e_1)}.$$

Thus, at the free trade equilibrium we have:

$$x_{11}(e_1, e_2) = \frac{\alpha_{11} Y_1(e_1)(1+t)}{1+\alpha_{11} t}, \qquad x_{12}(e_1, e_2) = \alpha_{21} Y_2(e_2)$$

$$x_{21}(e_1, e_2) = \frac{\alpha_{12} Y_1(e_1)}{1+\alpha_{11} t}, \qquad x_{22}(e_1, e_2) = \alpha_{22} Y_2(e_2).$$

Consider the indirect utility functions $V_1^t(e_1, e_2)$ and $V_2^t(e_1, e_2)$ resulting from the above equilibrium allocation. Given the structure of the above equilibrium consumption levels one immediately observes that the equilibrium values of e_1 and e_2 are not affected by the value of t. More specifically, we have:

$$V_1^t(e_1, e_2) = \frac{1+t}{1+\alpha_{11} t} \cdot V_1^0 \text{ and } V_2^t(e_1, e_2) = \frac{1}{1+\alpha_{11} t} \cdot V_2^0,$$

with $V_i^0(e_1, e_2)$ denoting indirect utility for the case $t = 0$. Thus, the introduction of a tariff does not change equilibrium values of the environmental standards. One of the reasons of this result is certainly provided by complete specialization in free

trade: production of the two commodities is cet. par. not affected by the imposition of a tariff. Of course, the change in international prices due to the tariff has a positive effect on the welfare of country 1, which can improve its competitive situation under the tariff.

6.2 Transfer of Units of the Endowment

Next we consider a transfer $\Delta > 0$ of the endowment of country 1 to country 2. The analysis is again carried out for the case of free trade where environmental effects can be regional or global in nature. (An analogous analysis could be extended for the case of autarky.)

For the endowment values $Z_1^\Delta := Z_1 - \Delta$ and $Z_2^\Delta := Z_2 + \Delta$ and a pair of environmental standards e_1 and e_2, we derive the following expressions for equilibrium allocations:

$$x_{11}^\Delta(e_1, e_2) = \alpha_{11}\beta_{11}(1 - e_1)Z_1^\Delta, \qquad x_{12}^\Delta(e_1, e_2) = \alpha_{21}\beta_{22}(1 - e_2)Z_2^\Delta,$$
$$x_{21}^\Delta(e_1, e_2) = \alpha_{12}\beta_{11}(1 - e_1)Z_1^\Delta, \qquad x_{22}^\Delta(e_1, e_2) = \alpha_{22}\beta_{22}(1 - e_2)Z_2^\Delta.$$

Again, there is no effect on the equilibrium values of the environmental standards; welfare may either increase or decrease depending on the precise values of the various parameters. This result is generated by the assumption of homothetic utility functions: a transfer of endowments yields a proportional change in demand for both commodities and for both consumers.

6.3 Transfer of Units of a Commodity

We now assume that country 1 transfers an amount Δ of commodity 1 to country 2. For the sake of simplicity, we restrict our analysis to the case of international environmental problems with $\gamma_1 = \gamma_2 = 0.5$ in an autarky equilibrium. A similar analysis should hold for the case of a free trade equilibrium.

Let us first consider the equilibrium conditions for country 1. For the production levels x_{11} and x_{12} and autarky equilibrium prices $p_{11} = \beta_{12}$ and $p_{12} = \beta_{11}$ we obtain

for fixed environmental standards e_1 and e_2:

$$\begin{aligned} p_{11}x_{11} + p_{12}x_{12} &= p_{11}\beta_{11}(1-e_1)Z_1, \\ p_{11}(x_{11}-\Delta)\alpha_{12} &= p_{12}x_{12}\alpha_{11}. \end{aligned}$$

Solving these equations for the production levels x_{11} and x_{12} of the two commodities we arrive at:

$$\begin{aligned} x_{11} &= \alpha_{11}\beta_{11}(1-e_1)Z_1 + \alpha_{12}\Delta \\ x_{12} &= \alpha_{12}\beta_{12}(1-e_1)Z_1 - \frac{\beta_{12}}{\beta_{11}}\alpha_{12}\Delta \end{aligned}$$

As a consequence, the equilibrium consumption levels of the two commodities are given by:

$$\begin{aligned} x_{11}^{\Delta}(e_1,e_2) &= x_{11} - \Delta = \alpha_{11}\beta_{11}(1-e_1)Z_1 - \alpha_{11}\Delta \\ x_{12}^{\Delta}(e_1,e_2) &= x_{12} = \alpha_{12}\beta_{12}(1-e_1)Z_1 - \frac{\beta_{12}}{\beta_{11}}\alpha_{12}\Delta \end{aligned}$$

In a completely analogous way one obtains autarky equilibrium values for the production quantities of the two commodities in country 2:

$$\begin{aligned} x_{21} &= \alpha_{21}\beta_{21}(1-e_2)Z_2 - \alpha_{22}\Delta \\ x_{22} &= \alpha_{22}\beta_{22}(1-e_2)Z_2 + \frac{\beta_{22}}{\beta_{21}}\alpha_{22}\Delta \end{aligned}$$

Again, the equilibrium consumption levels are relevant for welfare considerations:

$$\begin{aligned} x_{21}^{\Delta}(e_1,e_2) &= x_{21} + \Delta = \alpha_{21}\beta_{21}(1-e_2)Z_2 + \alpha_{21}\Delta \\ x_{22}^{\Delta}(e_1,e_2) &= x_{22} = \alpha_{22}\beta_{22}(1-e_2)Z_2 + \frac{\beta_{22}}{\beta_{21}}\alpha_{22}\Delta \end{aligned}$$

Observe that equilibrium consumption levels are related to each other in the following way:

$$x_{11}^{\Delta}(e_1,e_2) = \frac{\beta_{11}\alpha_{11}}{\beta_{12}\alpha_{12}} \cdot x_{12}^{\Delta}(e_1,e_2) \text{ and } x_{21}^{\Delta}(e_1,e_2) = \frac{\beta_{21}\alpha_{21}}{\beta_{22}\alpha_{22}} \cdot x_{22}^{\Delta}(e_1,e_2).$$

In the next step, we derive the reaction curves with respect to the optimally chosen environmental standards. Observe that for the indirect utility we have $V_1^{\Delta}(e_1, e_2) = (x_{11}^{\Delta}(e_1, e_2))^{\alpha_{11}}(x_{12}^{\Delta}(e_1, e_2))^{\alpha_{12}}(E_1)^{\alpha_{13}}$. In view of the above relationship between x_{11}^{Δ} and x_{12}^{Δ} it is thus sufficient to apply $V_1^{\Delta}(e_1, e_2) \approx x_{11}^{\Delta}(e_1, e_2)(E_1)^{\alpha_{13}}$ for deriving the optimal reaction of country 1 to e_2. Similarly, it is sufficient to consider $V_2^{\Delta}(e_1, e_2) \approx x_{21}^{\Delta}(e_1, e_2)(E_2)^{\alpha_{23}}$ for obtaining the optimal reaction of country 2 to e_1.

By using equations $\partial V_i^{\Delta}(e_1, e_2)/\partial e_i = 0$ for $i = 1, 2$ we arrive at the following expressions for the reaction curves, if we assume $\gamma_1 = \gamma_2 = 0.5$:

$$e_1^{\Delta}(e_2) = \frac{\alpha_{13}\beta_{11}Z_1 - \alpha_{13}\Delta - \beta_{11}Z_1e_2}{\beta_{11}Z_1(1+\alpha_{13})},$$

$$e_2^{\Delta}(e_1) = \frac{\alpha_{23}\beta_{21}Z_2 - \alpha_{23}\Delta - \beta_{21}Z_2e_1}{\beta_{21}Z_2(1+\alpha_{23})}.$$

Solving these conditions for the values of the Nash equilibrium $(e_1^{A,\Delta}, e_2^{A,\Delta})$ one obtains:

$$e_1^{A,\Delta} = \frac{(\alpha_{13} + \alpha_{13}\alpha_{23} - \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2 - \alpha_{13}(1+\alpha_{23})\beta_{21}Z_2\Delta - \alpha_{23}\beta_{11}Z_1\Delta}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2},$$

$$e_2^{A,\Delta} = \frac{(\alpha_{23} + \alpha_{13}\alpha_{23} - \alpha_{13})\beta_{11}Z_1\beta_{21}Z_2 + \alpha_{23}(1+\alpha_{13})\beta_{11}Z_1\Delta + \alpha_{13}\beta_{21}Z_2\Delta}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2}.$$

We consider next the indirect utilities $V_1^{\Delta}(e_1^{A,\Delta}, e_2^{A,\Delta})$ and $V_2^{\Delta}(e_1^{A,\Delta}, e_2^{A,\Delta})$ in the Nash equilibrium. For the derivative $\partial V_1^{\Delta}(e_1^{A,\Delta}, e_2^{A,\Delta})/\partial\Delta$ at $\Delta = 0$, we can derive the following formula:

$$\frac{\partial V_1^{\Delta}(e_1^{A,\Delta}, e_2^{A,\Delta})}{\partial\Delta} \mid_{\Delta=0} > 0 \Longleftrightarrow \frac{\alpha_{23}(\beta_{11}Z_1 - \beta_{21}Z_2)}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2} + 1 > 0.$$

Similarly, the corresponding condition for welfare in country 2 reads:

$$\frac{\partial V_2^{\Delta}(e_1^{A,\Delta}, e_2^{A,\Delta})}{\partial\Delta} \mid_{\Delta=0} > 0 \Longleftrightarrow \frac{\alpha_{13}(\beta_{11}Z_1 - \beta_{21}Z_2)}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2} + 1 > 0.$$

Thus, $\beta_{11}Z_1 > \beta_{21}Z_2$ is a sufficient condition for an increase in welfare in both countries for small values of Δ.

Moreover, if we consider

$$e_1^{A,\Delta} + e_2^{A,\Delta} = \frac{2\alpha_{13}\alpha_{23}\beta_{11}Z_1 - \beta_{21}Z_2 + \alpha_{13}\alpha_{23}\Delta(\beta_{11}Z_1\beta_{21}Z_2)}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2}$$

then we observe that the same condition also guarantees an increase in the sum of the environmental standards.

For arbitrary values of Δ the derivatives of the indirect utility functions with respect to Δ are given by:

$$\begin{aligned}
\frac{\partial V_1^{\Delta}}{\partial \Delta} &= \frac{\alpha_{23}\beta_{11}Z_1}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2}(\beta_{11}Z_1 - \beta_{21}Z_2)e^{A,\Delta} + \\
&+ \alpha_{13}(1 - e_1^{A,\Delta})\beta_{11}Z_1 - \alpha_{13}\Delta, \\
\frac{\partial V_2^{\Delta}}{\partial \Delta} &= \frac{\alpha_{13}\beta_{21}Z_2}{(\alpha_{13} + \alpha_{13}\alpha_{23} + \alpha_{23})\beta_{11}Z_1\beta_{21}Z_2}(\beta_{11}Z_1 - \beta_{21}Z_2)e^{A,\Delta} + \\
&+ \alpha_{23}(1 - e_2^{A,\Delta})\beta_{21}Z_2 + \alpha_{23}\Delta.
\end{aligned}$$

As an immediate consequence, welfare in country 2 will always increase given the above condition, whereas welfare in country 1 may decrease for larger values of Δ.

7 Final Remarks

In this paper we investigated some of Bhagwati's genuine problems, interfering with free trade and the environment. In a model based on comparative advantage we demonstrated that environmental standards can be different in free trade equilibrium although the propensities towards the protection of the environment are identical. Thus, the issue of "unfair trade" is problematic at least as long as it is based on differing environmental standards alone. With respect to the problem of "losing one's higher standards" our results are ambiguous, at least for the case of international environmental problems.

"Immiserization" can happen, both for the case of regional and international environmental problems. The reason is, however, a too strong emphasis on the

environmental issues, and not an increasing degradation of the environment in equilibrium.

Some results on the possibilities of affecting the other country's environmental policy by regular instruments of the trade policy demonstrate that only the transfer of units of a consumption commodity may have the required effect. These results depend, however, substantially on the structure of the model.

8 Appendix

In order to prove Results 5.1.2 and 5.1.3 we will use the following lemma:

Lemma: (i) The inequality $E_1^T > E_1^A$ holds if and only if

$$Q_1 + Q_2 + Q_3 + Q_4 > 0,$$

where

$$Q_1 = \gamma_1\gamma_2(\gamma_1 + \gamma_2 - 1)\alpha_{13}(\alpha_{22} + \alpha_{23} - \alpha_{11}\alpha_{22} - \alpha_{11}\alpha_{22}\alpha_{23}),$$

$$Q_2 = \gamma_1^2\gamma_2^2\alpha_{13}\alpha_{23}(\alpha_{22} + \alpha_{23} - \alpha_{11} - \alpha_{11}\alpha_{23}),$$

$$Q_3 = \gamma_1^2\gamma_2(1 - \gamma_1)\alpha_{13}\alpha_{23}(\alpha_{11} + \alpha_{13} - \alpha_{22} - \alpha_{22}\alpha_{13}),$$

$$Q_4 = (1 - \gamma_1)\gamma_1(\gamma_1 + \gamma_2 - 1)\alpha_{22}\alpha_{13}(\alpha_{11} - 1).$$

(ii) The inequality $E_2^T > E_2^A$ holds if and only if

$$R_1 + R_2 + R_3 + R_4 > 0,$$

where

$$R_1 = \gamma_1\gamma_2(\gamma_1 + \gamma_2 - 1)\alpha_{23}(\alpha_{11} + \alpha_{13} - \alpha_{11}\alpha_{22} - \alpha_{11}\alpha_{22}\alpha_{13}),$$

$$R_2 = \gamma_1^2\gamma_2^2\alpha_{13}\alpha_{23}(\alpha_{11} + \alpha_{13} - \alpha_{22} - \alpha_{22}\alpha_{13}),$$

$$R_3 = \gamma_1\gamma_2^2(1 - \gamma_2)\alpha_{13}\alpha_{23}(\alpha_{22} + \alpha_{23} - \alpha_{11} - \alpha_{11}\alpha_{23}),$$

$$R_4 = (1 - \gamma_2)\gamma_2(\gamma_1 + \gamma_2 - 1)\alpha_{11}\alpha_{23}(\alpha_{22} - 1).$$

Both assertions follow from (6)-(7) and (14)-(15) by evaluating the differences $E_i^T - E_i^A = \gamma_i e_i^{I,T} + (1-\gamma_i)e_j^{I,T} - (\gamma_i e_i^{I,A} + (1-\gamma_i)e_j^{I,A})$ for $i = 1, 2$ and $j \neq i$.□

Proof of Result 5.1.2 Consider country 1. Note that if $\gamma_1 = \gamma_2 = 0.5$, then $Q_1 = Q_4 = 0$. But then

$$Q_2 + Q_3 = \frac{1}{16}\alpha_{13}\alpha_{23}(\alpha_{22} - \alpha_{22}\alpha_{13} + \alpha_{11} - \alpha_{11}\alpha_{23})) > 0,$$

which, by the Lemma, implies that $E_1^T > E_1^A$. The assertion for country 2 is proved in a similar manner.□

Proof of Result 5.1.3 Let $\gamma_1 + \gamma_2 > 1$. This implies that $\gamma_1 > 1 - \gamma_2$ and $\gamma_2 > 1 - \gamma_1$, that guarantees that both $Q_1 + Q_4$ and $R_1 + R_4$ are positive numbers. Assume that $\alpha_{11} \leq \alpha_{22}$. Then $Q_2 > 0$ and, moreover,

$$Q_2 + Q_3 > \gamma_1^2\gamma_2(1 - \gamma_1)\alpha_{13}\alpha_{23}(\alpha_{23} - \alpha_{11}\alpha_{23} + \alpha_{13} - \alpha_{22}\alpha_{13})) > 0,$$

that implies that, at least one of the countries would raise its state of environment under free trade.

To show that one of the countries may indeed experience a decline of its state of environment, choose $\gamma_1 = 1$, $\gamma_2 = 0.5$, $\alpha_{13} = \alpha_{23} = 1$. Then $Q_3 = Q_4 = 0$, and

$$Q_2 + Q_3 = \frac{1}{2}(\alpha_{22} - \alpha_{11}\alpha_{22} - \alpha_{11}),$$

which is negative whenever $\alpha_{11} > \alpha_{22}$. Thus, $E_1^T < E_1^A$.□

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