Environment and Development Economics 5 (2000): 361–375

Trade and environmental distortions: coordinated intervention

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ABSTRACT. Free trade may not improve welfare when environmental distortions exist. We study the coordination of trade and environmental policies when the distortion is loose property rights governing resources. Using the dual approach of Dixit and Norman (1980), we trade out 'iso-welfare' curves in the space of the degree of environment distortion and the level of the import tariff. We use these curves to find necessary and sufficient conditions for disproportionate reforms, piecemeal or discrete, to be welfare improving. We also find that the needed reduction in the distortion to make trade welfare improving increases as the environmental stock increases, the productivity of the environmentally intensive good increases, or when the country is a large exporter of the environmentally intensive good.

Do domestic environmental distortions justify trade barriers? Should joining free trade agreements be accompanied by adopting better resource and environmental management practices? These questions frequently come up in trade negotiations and international environmental disputes, and have manifested themselves in such politically sensitive issues as environmental policy harmonization, greening the GATT, etc. Economists have applied the theory of second best to study the implications of free trade in the presence of environmental distortions, and, not surprisingly, have found that free trade does not necessarily improve individual or aggregate welfare. However, they also qualified this finding, stating that it does not lead to the conclusion that free trade should be abolished. Rather, they argued, it means that trade should be adopted with the reduction of domestic environmental distortions (see Chichilnisky, 1994; Brander and Taylor, 1998; Copeland and Taylor, 1995; and Karp, Sacheti, and Zhao, forthcoming).

The purpose of this paper is to identify the *degree* of environmental distortion reduction that is needed to make a move towards free trade welfare-improving. The premise is that if a small step towards free trade requires a big step in reducing environmental distortions to maintain the welfare level, then free trade must be accompanied by the correction of environmental distortion and trade barriers based on environmental

I acknowledge the Global Environment and Trade Study and the MacArthur Foundation for (partial) financial assistance. I would like to thank Scott Barrett and two anonymous referees for helpful comments. The usual disclaimer applies.

practices are justified. However, if insignificant improvements in environment management are sufficient to make freer trade welfare improving, then environmental distortion should not justify any practically meaningful trade barriers.

We extend the model of Brander and Taylor (1998) to allow for different degrees of static property rights over the environment stock. Using the dual approach of Dixit and Norman (1980), we trace out an 'iso-welfare' curve in the space of the degree of environmental distortion and the level of import tariffs. Following Karp, Sacheti, and Zhao (forthcoming), we represent the level of distortion by the number of extractors of a common property source. A higher degree of distortion corresponds to a lower degree of (static) property rights over the resource. The degree of free trade is represented by a tariff on the import of the resource-intensive good.

The answers to the questions that we posed at the beginning depend on the shape of the iso-welfare curves. The shape also reveals which policy, entering free trade agreements or reducing environmental distortion, is more effective in improving welfare. We will study how the shape of the iso-welfare curves depends on factor endowments, technology, and preferences.

There is a growing body of literature on coordinating trade and environmental policies (Olph, 1997/8). Markusen (1975b), Markusen (1975a), Baumol and Oates (1988), and Krutilla (1991) study optimal intervention in a world of second best, such as choosing optimal tariffs *given* environmental distortions. The basic message here is that one distortion affects the optimal policy that aims to correct other distortions. Copeland (1994) and Beghin, Roland-Holst, and Mensbrugghe (1997), on the other hand, provide sufficient conditions for a piecemeal reform of only one of the distortions to prove welfare improving. Based on the iso-welfare curves, our paper studies the optimal second-best intervention and the sufficient conditions for a welfare-improving reform of all degrees of distortion. Further, while Hatta (1977) and Beghin, Roland-Holst and Mensbrugghe (1997) have shown that equiproportional reduction of all the distortions improves welfare, we can delineate disproportionate reductions that are welfare improving and reducing, again based on the iso-welfare curves. Finally, while the above literature mainly studies pollution as the form of environmental distortion, we focus on weak property rights over the environmental services. As we will see, this distortion requires some modification of the conditions for equilibrium in the Dixit and Norman (1980) dual model.

The paper is organized as follows. Section 1 studies the autarky economy and builds the basic model. It also investigates how property right distortions change the characteristics of the revenue function and the supply function. Section 2 considers the case of a small open economy and section 3 studies a large open economy. Section 4 discusses the results and concludes the paper.

1. The autarky economy

Extending Brander and Taylor (1998), we consider an economy of two goods, the manufactured good M and the harvested good H. Both goods are produced using labour, but the harvested sector also uses natural

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resource stock. M is produced with a constant returns to scale technology given by $M = L_M$ after choosing proper units of measurement. H is produced with a technology given by

$$H = \alpha Z^{1/2} L_H^{1/2} \tag{1}$$

where α is a scale factor, Z is the resource stock, and L_H is the labour employed in the H sector. The economy has a labour endowment of L, which is supplied perfectly inelastically. The resource stock evolves according to its growth rate and the harvest rate H, but in the static model, we take Z as fixed.

Good M is the numeraire with price 1, thus the wage rate is $w = 1$ if M is produced in the economy. We let p represent the price of H. There is no dynamic property rights over the resource stock, so that the price of Z is zero. Moreover, there is imperfect static property rights as well. Following Dasgupta and Heal (1979), Chichilnisky (1994), and Karp, Sacheti, and Zhao (forthcoming), we assume that there are n identical extractors, and the output of each is the portion of the total output equal to its share of the total labour input. In particular, let L_i be the labour input of firm i; this firm's output of H is then given by

$$\alpha Z^{1/2} \left(\sum_{j=1}^{n} L_j\right)^{1/2} \frac{L_i}{\sum_{j=1}^{n} L_j}$$

Firms take p and $w = 1$ as given, and we can show that the total output of H is

$$H^p = \alpha^2 \delta Z p \tag{2}$$

where superscript p denotes production, and $\delta = 1 - 1/(2n)$ measures the level of property rights. There is no property rights when n is infinity or δ is close to 1, and there is perfect property rights when $n = 1$ or $\delta = 1/2$.

Given p, (2) tells how much H^p is produced. From (1), we can calculate how much labour is employed in the H sector. Since the rest of the labour force is employed in sector M (note that M has a constant returns to scale technology), we know the output of M is given by

$$M^p = \bar{L} - \alpha^2 \delta^2 Z p^2 \tag{3}$$

We assume that the labour endowment $\bar{L}$ is high enough so that M is always produced in the economy.

We will use a dual approach in the following part of the paper, so we need to find the revenue function. As a result of the property right distortions, the revenue function cannot be found by appropriately choosing the output of M and H to maximize the total revenue $M^p + pH^p$. Instead, we have to calculate the revenue function directly from the supply functions of H and M in (2) and (3) multiplied by their respective prices.

$$r(p, \bar{L}, \delta, Z) = \bar{L} + \alpha^2 \delta (1 - \delta) Z p^2 \tag{4}$$

The revenue function also has different properties from the conventional revenue function. In particular, the supply function of H is different from r_p, the partial derivative of r with respect to p. Rather

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$$H^p = \frac{r_p}{2(1-\delta)} \tag{5}$$

There are $\bar{L}$ individuals, each endowed with one unit of labour. Each individual's utility is given by a constant returns to scale Cobb–Douglas function

$$u = h^{\beta} m^{1-\beta} \tag{6}$$

where h and m are the consumption of harvested good H and manufactured good M. It is straightforward to show that each individual's expenditure function is

$$e(p, u) = \frac{u}{A} p^{\beta} \tag{7}$$

where $A = \beta^{\beta}(1-\beta)^{1-\beta}$. Since the utility function is homogeneous of degree one, (7) also represents the expenditure function of the entire economy when u is the aggregate utility level, i.e. the welfare level. We will follow the latter interpretation throughout the paper.

The autarky equilibrium is given by

$$e(p, u) = r(p, \bar{L}, \delta, Z) \tag{8}$$

$$e_p(p, u) = H^p(p, \bar{L}, \delta, Z) \tag{9}$$

Solving (8) and (9), we find the autarky equilibrium price as

$$p^a = \frac{1}{\alpha} \sqrt{\frac{\beta \bar{L}}{\delta(1-\beta+\beta\delta)Z}}$$

p^a is decreasing in Z and δ, since higher resource stock and imperfect property rights raise the production of H. We can also calculate the welfare level u, and verify that it is decreasing in δ when $\delta > 1/2$. That is, imperfect property rights reduces the autarky welfare level, so that the country in autarky always has incentive to reduce property right distortions.

2. A small open economy

In this section, we consider the case where the country is open to international trade, and take the world price p_w as given. We assume that the country imposes an import tariff or export subsidy at the level of t, so that the domestic price is

$$p = p_w + t \tag{10}$$

We also want to find an 'iso-welfare curve' such that combinations of t and δ give rise to the same welfare level in the economy. This curve would tell the necessary adjustment needed to the other when we reform one of the distortions.

Let H^x be the export of H, then the trade equilibrium is given by

$$e(p, u) = r(p, \bar{L}, \delta, Z) - tH^x \tag{11}$$

$$e_p(p, u) = H^p(p, \bar{L}, \delta, Z) - H^x \tag{12}$$

and (10). Totally differentiating (11) and (12), we get

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$$e_u du + t dH^x = (r_p - H^x - e_p)dt + r_\delta d\delta \tag{13}$$

$$e_{pu} du + dH^x = (H^p_p - e_{pp})dt + H^p_\delta d\delta \tag{14}$$

Solving for du yields

$$du = \frac{1}{D}\{[r_p - H^x - e_p - t(H^p_p - e_{pp})]dt + (r_\delta - tH^p_\delta)d\delta\} \tag{15}$$

where $D = e_u - te_{pu} > 0$.[1]

Given t, the optimal property right distortion δ is determined by $du/d\delta = 0$. The inverse of the optimal property right function is

$$t^\delta(\delta) = \frac{r_\delta}{H^p_\delta} = \frac{1 - 2\delta}{2\delta} p_w \qquad \text{for } t < 0 \tag{16}$$

When $t \geq 0$, the optimal property right is given by $\delta = 1/2$. That is, when $t < 0$, i.e. when there is a subsidy (duty) for the import (export) of H, having a certain degree of loose property rights is optimal. However, when there is import tariff (or export subsidy) of H ($t \geq 0$), only perfect property right is optimal.

Given δ, the optimal tariff is determined by $du/dt = 0$, or

$$t^t(\delta) = \frac{r_p - H^x - e_p}{H^p_p - e_{pp}} \tag{17}$$

The denominator is positive, since H^p is increasing and e is concave in p. From (12), we know $r_p/2(1 - \delta)) - H^x - e_p = 0$. $\delta > 1/2$ then implies that the numerator in (17) is negative (note that $r_p > 0$). Therefore, if there is any property right distortion in producing the harvest good H, the optimal import tariff is negative, that is, the government should subsidize (tax) the import (export) of H. This point is intuitive: $t < 0$ lowers the domestic price of H and discourages the production of H, reducing the negative impacts of imperfect property rights.[2]

Note from (16) that $t^\delta(\delta)$ is decreasing in δ. We can also show that $t^t(\delta)$ is decreasing in δ, i.e. more environmental distortion means heavier import subsidies. To see this, note that from (12) and (5), the numerator of (17) equals $r_p(1 - 1/(2(1 - \delta)))$. Taking the derivative of this expression with respect to δ and using (4), we can verify that the derivative is non-positive. H^p_p is increasing in δ, and e_{pp} is increasing in u, which is decreasing in δ when $t = t^t(\delta)$ (we will show this later on). Thus the denominator of (17) is increasing in δ.

[1] This is the stability condition, which is satisfied by our model. Hatta (1977) gives a detailed discussion on this condition.

[2] Chichilnisky (1994) showed that for the case of *subsistence* labours, lower price of H may actually lead to higher production, that is, H^p would be *decreasing* in p. We do not study a subsistence economy in this paper (labour is assumed to be freely movable between the harvest and manufacturing sectors), but if the economy is indeed a subsistence economy, our result should be modified: when the property right is imperfect, the optimal tariff should be *positive* to discourage the harvest activity. It would be interesting as an extension of this paper to study the features of the iso-welfare curves in a subsistence economy.

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From (15), we know the slope of the iso-welfare curve $du = 0$ is given by

$$\frac{dt}{d\delta} = -\frac{r_\delta - tH^p_\delta}{r_p - H^x - e_p - t(H^p_p - e_{pp})} \tag{18}$$

Thus, in the $\delta - t$ space, the iso-welfare curve is negatively sloped at a point (δ, t) above or below the two curves, $t^t(\cdot)$ and $t^\delta(\cdot)$. It has a positive slope between the two curves.

We can then graph the two curves $t^\delta(\delta)$ and $t^t(\delta)$ together with the iso-welfare curves in the $\delta - t$ space. Without trade distortion, i.e. when $t = 0$, the optimal property rights structure is $\delta = 1/2$. Similarly, with perfect property rights $\delta = 1/2$, the optimal tariff is zero. Thus the two curves $t^\delta(\delta)$ and $t^t(\delta)$ cross at $(1/2, 0)$. Further, we can show that $t^t(\cdot)$ lies above $t^\delta(\cdot)$ for $\delta > 1/2$. To see this, suppose that t^t lies below t^δ at some δ^*. Then the iso-welfare curve $du = 0$ has a slope of zero at $(\delta^*, t^t(\delta^*))$, and a slope of infinity at $(\delta^*, t^\delta(\delta^*))$, violating the fact that t^t determines the optimal tariff for a given δ, and t^δ determines the optimal δ given t. These curves are shown in figure 1.

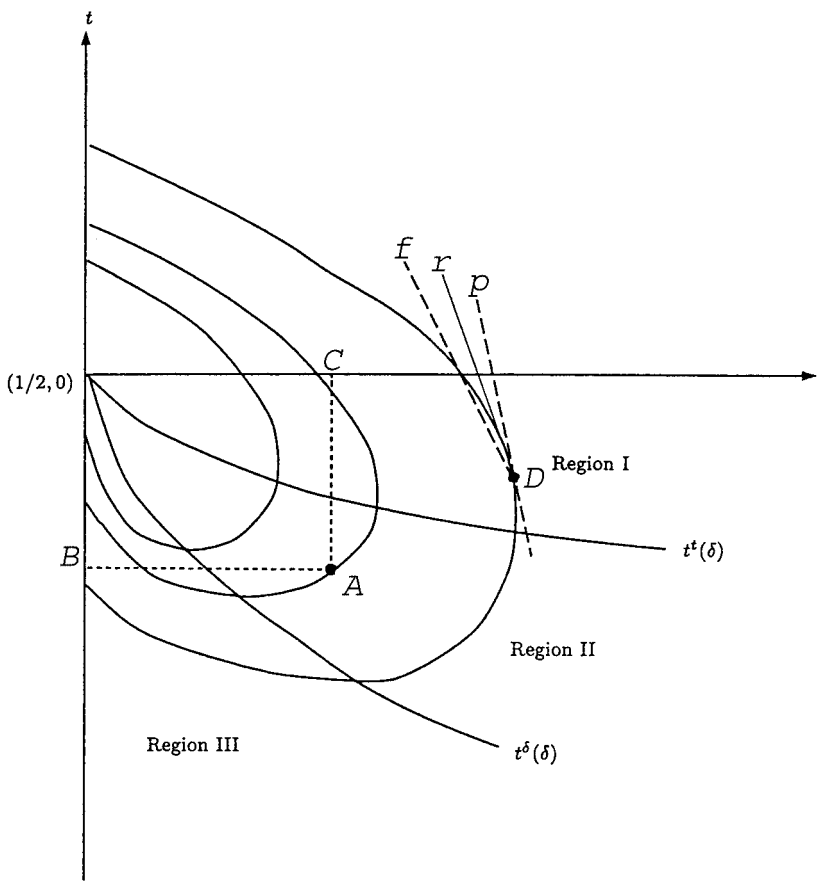

Figure 1. *Equal-welfare curves*

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The iso-welfare curves specified in figure 1 generate a rich set of results. First, completely correcting a single distortion may not improve welfare given the other distortion. For example, when the initial distortion is at point *A*, a complete reform of any one distortion would move the economy to points *B* or *C*, reducing its welfare.

Second, the fact that the t^t curve lies above the t^δ curve indicates that, in the long run, the following reform strategy will always converge to the optimal policy (1/2, 0): choosing the optimal t (or δ) given δ (or t). The starting point, i.e. which policy instrument is used first, does not matter. Figure 2 graphs two sequences of reform policies starting with different instruments, both converging to (1/2, 0). This observation also indicates that in the long run coordinating the two policy reforms is not crucial, as long as any single policy reform is the best response to the status quo.

Third, we can study piecemeal reforms using the iso-welfare curves. Since a positive t is never optimal with property right distortions, we concentrate on the case of $t \leqslant 0$. We divide the relevant $\delta - t$ space into three regions in figure 1, according to their position relative to the $t^t(\delta)$ and $t^\delta(\delta)$ curves. In region I, piecemeal reform of property right distortions always improves welfare. But moving towards free trade, i.e. raising t, always reduces welfare, unless it is accompanied by certain property right

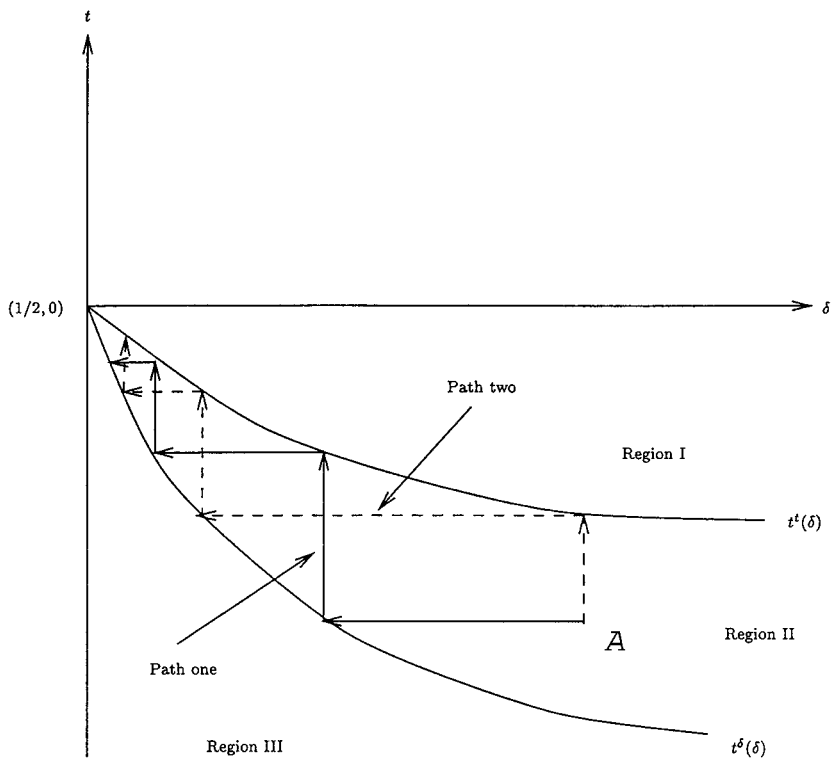

Figure 2. *Convergence of policy reforms*

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reforms. Similarly in region III, a piecemeal tariff reform towards free trade improves welfare, but any property right reform reduces welfare unless accompanied by appropriate tariff reform. In region II, any piecemeal reform is welfare improving.

If the current distortions are in region I, moving to freer trade requires property right reform. In this case, trade barriers are justified by domestic distortions. If the distortions are in regions II and III, a limited reduction of the trade barrier is always justified, even though moving completely to free trade may need reforming the property right structure. In this case, domestic distortions offer no excuse for maintaining current trade barriers, even though they may offer reasons for not completely removing trade barriers.

While it is clear that equiproportional reduction of the distortions improves welfare, we can rely on figure 1 to study disproportionate reductions. Suppose the current economy is at point *D* in figure 1. A disproportionate reform is represented by a line starting from point *D* in the upper-left direction, e.g. *Dr*. For a small reduction, the tangency line to the iso-welfare curve, *Dp*, serves as the boundary for the reduction to be welfare improving. If the slope of the 'reform line' is smaller than *Dp*, the piecemeal reform would improve the economy's welfare; otherwise it would reduce welfare. For disproportionate reforms of a certain size, the boundary is given by a line from *D* to the point where the iso-welfare curve crosses the δ axis, i.e. line *Df*. Then, if the slope of the reform line is smaller than *Df*, the reform is welfare-improving; otherwise, it may reduce welfare. For example, a reform in the direction of *Dr* improves welfare if the scale of the reform is small, but reduces welfare if the scale is too large.

Effects of resource stock Z

We now study how resource stock *Z* affects the relationship between the two kinds of distortion reductions. Our model is essentially a static model, treating *Z* as fixed. The purpose of this section is to illustrate the different optimal coordinations of the environmental and trade policies implied by different resource stocks. This may be relevant in comparing the policies of different countries or the same economy at different levels of resource stock. We first show how the iso-welfare curves and $t^t(\cdot)$ and $t^\delta(\cdot)$ curves depend on *Z*. From (16), we know $t^\delta(\cdot)$ is independent of *Z*: the optimal property right distortion given the tariff does not depend on the resource stock. The reason is that the optimal δ balances its effect on the GDP, r_δ, and that on the tax revenue, $-tH^p_\delta$. The two effects are both linear in *Z* in our model, so that changing *Z* does not affect the optimal balance.[3] For the $t^t(\delta)$ curve, we can show

Proposition 1 *As Z increases,* $t^t(\delta)$ *increases for* $\delta > 1/2$. *That is, the* $t^t(\delta)$ *curve rotates up around* $(1/2, 0)$ *in the* $\delta - t$ *space.*

Proof The numerator of (17) equals $r_p(1 - 1/(2(1 - \delta)))$. Further, we know

$$r_p = 2\alpha^2\delta(1 - \delta)Zp, \tag{19}$$

[3] This feature is based on the special functional forms assumed in our model. It is not a general result.

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$$H_p^p = \alpha^2 \delta Z, \tag{20}$$

$$e_{pp} = \frac{u\beta(\beta - 1)p^{\beta-2}}{A} \tag{21}$$

$$u = \frac{A}{p - \beta t}\left(\alpha^2\delta(1 - \delta)Zp^{3-\beta} - \alpha^2\delta Ztp^{2-\beta} + \bar{L}p^{1-\beta}\right). \tag{22}$$

Substituting (19)–(22) into (17), and dividing through by Z, we get proposition 1.

Thus, as the resource stock increases, the optimal trade barrier decreases for a given property right distortion. To see the intuition, consider the case where the country exports H. As Z increases, the benefit of exporting H increases as the real comparative advantage of high stock rises compared with the 'apparent' comparative advantage owing to imperfect property rights. Thus the optimal export duty should be lower to encourage the export of H.

As the t^t curve shifts up, region II becomes bigger and region I becomes smaller (figure 3). The region where a piecemeal reform of tariff is welfare

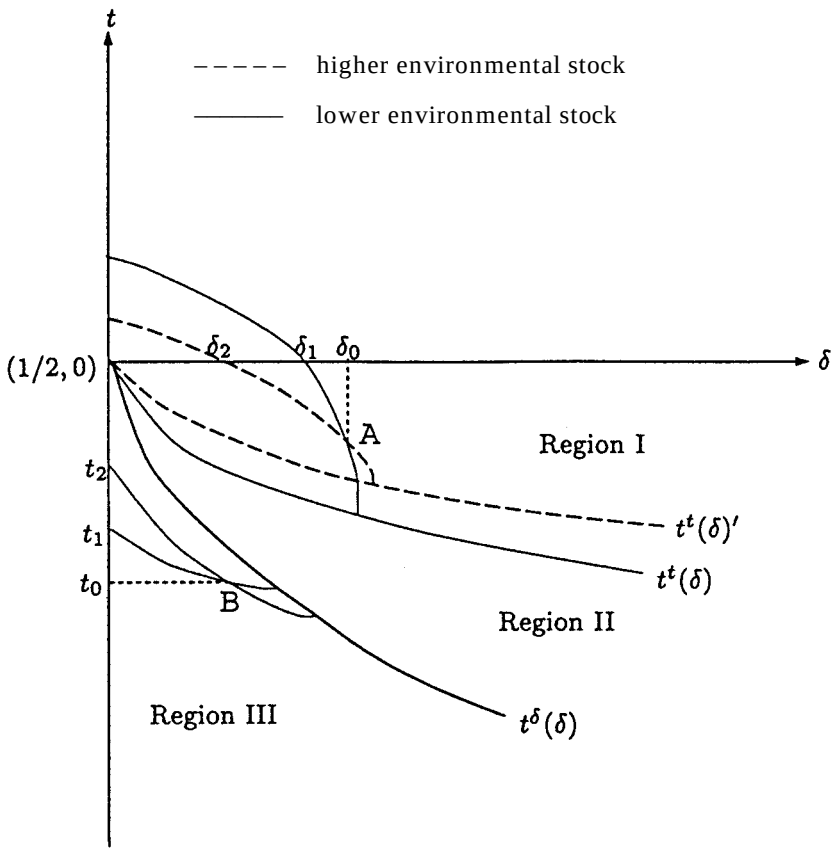

Figure 3. *Effects of higher environmental stock*

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improving (regions II and III) becomes bigger and the region where a piecemeal reform of property rights is welfare improving (regions I and II) remains unchanged. Piecemeal reform of tariffs is more likely to be important as the stock increases.

The shape of the iso-welfare curve is also different as the resource stock changes.

Proposition 2 *As resource stock Z increases, the slope of the iso-welfare curve becomes smaller in region I, and higher in regions II and III.*

Proof We know

$$r_{\delta} = \alpha^2(1 - 2\delta)Zp^2 \tag{23}$$

$$H^p_{\delta} = \alpha^2 Zp. \tag{24}$$

Substituting equations (19)–(24) into (18), and dividing through by Z, we get proposition 2.

The slope change of the iso-welfare curve indicates that when the economy is in regions I and III, higher resource stock requires better coordination of the trade and property right policies. As shown in figure 3, completely removing one distortion requires a higher reduction in the other distortion as the resource stock changes. Suppose the country is currently at point A in region I. With a lower resource stock, completely removing the tariff requires reforming the property rights structure from δ_0 to δ_1 to prevent welfare loss. But when the resource stock is higher (with the iso-welfare curves represented by dashed lines), the required property right reform is more significant: from δ_0 to δ_2. Similarly, at point B in region III, completely reforming the property right structure requires reducing the export duty from $-t_0$ to $-t_1$. When Z increases, the required tariff reduction becomes higher: from $-t_0$ to $-t_2$. Thus for a country in region I with a larger resource stock, reducing property right distortion is more important when it joins free trade agreements. For economies in region II, the result becomes ambiguous.

Adopting a similar method, we can show that for stocks in regions I and III disproportionate reforms on both a small and large scale are less likely to improve welfare as the resource stock increases. For example, at point A, the slope of the iso-welfare curve is smaller for a larger resource stock, reducing the likelihood of welfare-improving disproportionate piecemeal reforms. This finding also indicates that coordinating both reforms is more important as the resource stock becomes larger.

Effects of other parameters

We can similarly study the effects of other parameters, in particular the production function parameter α, the utility function parameter β, and the labour stock L. From the production function of H in (1), we know increasing α^2 is equivalent to increasing Z. In fact, we can verify that α^2 and Z have the same effect on the shape of $t^t(\cdot)$, $t^{\delta}(\cdot)$, and the iso-welfare curves.

The parameters β and L only appear in e_{pp}, and we can verify that $\beta(1 - \beta)$ and L have the opposite effect of Z: when $\beta(1 - \beta)$ or L *decreases*, the $t^t(\cdot)$ curve shifts up, and the slope of the iso-welfare curve decreases in region I, and increases in regions II and III. $\beta(1 - \beta)$ decreases the more β diverges

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from 1/2, thus coordination of the two distortions becomes more important when the expenditure shares of the two goods become more unequal. A lower labour stock raises the relative endowment of Z, making the coordination more important.

3. A large open economy

In this section, we consider a large country that faces an excess demand function for H, given by $X(\cdot)$. We use capital letter X to denote the export of H by this country. The new equilibrium condition becomes

$$e(p, u) = r(p, \bar{L}, \delta, Z) - tX(p_w) \tag{25}$$

$$e_p(p, u) = H^p(p, \bar{L}, \delta, Z) - X(p_w) \tag{26}$$

and (10). Totally differentiating (25) and (26), we get

$$e_u du + (e_p - r_p + tX')dp = (tX' - X)dt + r_\delta d\delta \tag{27}$$

$$e_{pu} du + (e_{pp} - H^p_p + X')dp = X'\, dt + H^p_\delta d\delta \tag{28}$$

We can verify that[4]

$$D1 \equiv \begin{vmatrix} e_u & e_p - r_p + tX' \\ e_{pu} & e_{pp} - H^p_p + X' \end{vmatrix} < 0.$$

From (27) and (28), we know

$$\frac{dp}{d\delta} = \frac{1}{D1}(e_u H^p_\delta - e_{pu} r_\delta) < 0. \tag{29}$$

This result is intuitive: looser property rights lead to more production of H, reducing its price. As in the traditional trade model of Dixit and Norman (1980), an import tariff may or may not raise domestic price depending on the characteristics of the excess demand function $X(\cdot)$

$$\frac{dp}{dt} = \frac{1}{D1}[(e_u - e_{pu}t)\, X' + e_{pu}X] \tag{30}$$

$dp/dt > 0$ if the excess demand elasticity is high enough. We can verify that this is true in a North–South trade model where the other country is the same as the domestic economy except for its property rights structure δ.

Similar to the case of a small open economy, we wish to find the optimal tariff and property right functions, $t^t_x(\delta)$ and $t^\delta_x(\delta)$. Setting $du/dt = 0$ in (27) and (28) and adjusting, we get

$$t^t_x(\delta) \equiv \frac{rp - X\,(p - t) - e_p}{H^p_p - e_{pp}} + \frac{X\,(p - t)}{X'\,(p - t)} = t^t(\delta) + \frac{X}{X'} \tag{31}$$

Thus, when $X(\cdot)$ is such that the equilibrium price p_w is the same as in the small country case, the optimal tariff curve of the large country is below that of the small country by the amount $-X/X'$. No matter whether the

[4] To show this in our model, we need to substitute equations (19)–(24) into the expression $D1$. But this stability condition should be satisfied in a more general model.

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country exports or imports H, i.e. $X > 0$ or $X < 0$, X/X' is always negative. Given property right distortions, a large country has less incentive to correct its trade distortions. Note that when the property rights are perfect we obtain the conventional result that the optimal tariff $t = X/X' < 0$.

Setting $du/d\delta = 0$ in (27) and (28) and adjusting, we get

$$t_x^{\delta}(\delta) \equiv \frac{r_{\delta}}{H_{\delta}^{p}} + \frac{B}{X'(p-t)} = t^{\delta}(\delta) + \frac{B}{X'(p-t)} \tag{32}$$

where $B = (r_{\delta}(e^{pp} - H_p^p) - H_{\delta}^p(e_p - r_p))/(H_{\delta}^p)$. Noting that $X(p-t) = H^p - e^p$, we can show that $B - X \equiv Y = u\beta p^{\beta-1}(2\delta - 1)(1-\beta)/A > 0$. Equation (32) can then be written as

$$t_x^{\delta}(\delta) = t^{\delta}(\delta) + \frac{X}{X'} + \frac{Y}{X'} \tag{33}$$

Since $Y > 0$ and $X/X' < 0$, we know that the optimal property right curve of the large country is below that of the small country when the large country exports H (since then $X' < 0$). When the country imports H, $t_x^{\delta}(\delta) < t^{\delta}(\delta)$ for δ close to $1/2$, and the inequality *may* be reversed for larger δ. We concentrate on the case where the country exports H.

Figure 4 compares the optimal t and δ curves of the large and the small economies. For the large economy, region I becomes bigger and regions II

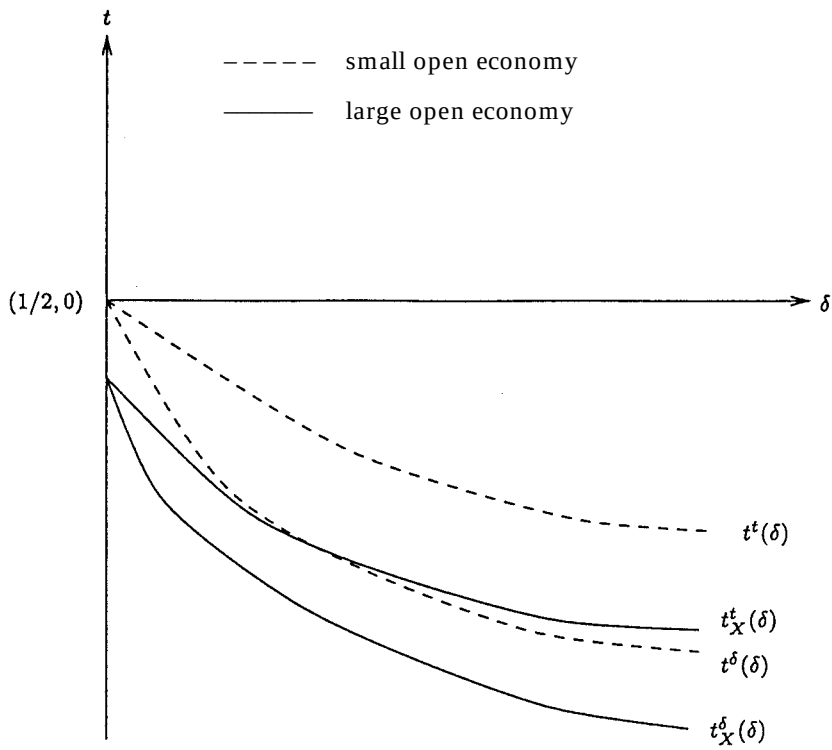

Figure 4. *Comparing the small and large economies*

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and III become smaller. It is thus more important for a large country to improve its property rights when it reduces the tariff barrier. It is less likely that reducing the tariff barrier itself improves welfare.

Appendix A shows that the iso-welfare curve of the large country is steeper in region I and less steep in regions II and III than that of a small country. Therefore, if the large country is in region I, tariff reform requires a greater reduction in property right distortion. If the country is in region III, property right reform requires less correction to tariffs.

4. Discussion and conclusion

In this paper, we studied the relationship between reducing trade tariffs and improving property rights over environmental resources. We identified situations where reducing a single distortion is welfare improving, and situations where reducing one distortion should be accompanied by reducing the other. If the reform always sets one distortion optimally given the other, then in the long run which distortion is reduced first does not matter, as the reform will converge to a point where both distortions are removed. But if the reform reduces distortions in an arbitrary way, then coordination becomes important when one of the distortions is much more significant than the other (i.e. in regions I and III of figures 3 and 4), or when the reduction is not gradual.

In many cases, moving to free trade, especially when completely removing trade distortion, reduces welfare with the presence of domestic property right distortions. We identified how much improvement in the property right structure is needed to make free trade welfare enhancing. The needed improvement increases as the environmental stock increases; the production of the environmentally intensive good becomes more efficient; the difference between expenditure shares of the two goods in the utility function increases, or the labour endowment decreases. The needed improvement is also greater when the country is a large exporter of the environmentally intensive good, compared with a small open economy.

We obtain the intuitive result that reducing one single distortion can improve welfare when the degree of this distortion is more than optimal given the other. When both distortions are more than optimal given the other, gradually reducing any distortion improves welfare. It is more likely for a large open economy than for a small open economy that reforming the property right structure alone improves welfare.

An essential tool developed in this paper is the iso-welfare curve in the space of tariff and property right distortions. The curve is useful in studying the standard issues, such as optimal policy intervention given other distortions, and implications of piecemeal reform of a single distortion. It is also useful to study the welfare implications of disproportionate reforms, extending the results of Hatta (1977).

There are some special features of the model that deserve comments. First, the property right structure is represented by the number of extractors in the harvested sector. These extractors generate negative externalities for each other since the harvest has decreasing returns to scale in the extraction activity. This is only one of many ways of modelling imperfect property rights. However, the major results of the paper do not

rely on this special form of property right distortion. What is important is that the distortion leads to more extraction than socially optimal.

Second, we assumed some special functional forms of the production functions and the utility function. These assumptions enable us to find analytical solutions for the optimal intervention and the iso-welfare curves. The shape of the iso-welfare curve should remain valid even if we relax some of these assumptions, so that our major results are in fact quite general. As an extension of this paper, it would be useful to study the features of the iso-welfare curve in a more general model.

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APPENDIX A: Comparing the iso-welfare curves of a large and a small open economies

For a small open economy, the slope of its iso-welfare curve in (18) can be rewritten as

$$\frac{dt}{d\delta} = -\frac{H^p_\delta}{H^p_p - e_{pp}} \frac{t^\delta(\delta) - t}{t^t(\delta) - t} \tag{34}$$

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Similarly, the slope of the iso-welfare curve of a large economy can be written as

$$\frac{dt^x}{d\delta} = -\frac{-H_{\delta}^{p}}{H_{p}^{p} - e_{pp}} \frac{t_{x}^{\delta}(\delta) - t}{t^{t}(\delta)_{x} - t} \tag{35}$$

From (31), (32) and $Y/M' < 0$, we know $dt^x / d\delta < dt / d\delta$ when $dt^x / d\delta < 0$, i.e. in region I, and $dt^x / d\delta > dt / d\delta$ when $dt^x / d\delta > 0$, i.e. in regions II and III.

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