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Environmental Policy in the Two-Country-Case

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In the every day discussion of environmental policy in an open economy, it is often argued that environmental policy reduces the comparative advantage of pollution-intensively producing sectors and that consequently environmental policy affects export opportunities of a country negatively. It is argued by both the export sector and the trade unions (fearing the employment effects) that policy makers should take into account the opportunity costs of environmental policy in terms of exports foregone. In contrast to this mercantilistic interpretation of the effects of environmental policy we can here show that environmental policy may improve the terms of trade. At the same time, environmental quality may increase. From this point of view the changes of environmental policy in an open economy can be judged in a more optimistic attitude.

For a closed economy the problem has been studied how environmental policy of a country influences comparative advantage [11]. Also we have analyzed the interrelation of gains from trade and environmental quality for an individual country [10]. In this paper we consider the two-country case and study how environmental policy in one country affects relative prices, international specialization and environmental quality. We assume a trade equilibrium in the initial situation and let the home country levy an emission tax. The frame of reference is a two-sector-model in which production generates pollutants as a joint product.

Section I presents the assumptions; Section II develops the model, and in Section III the implications of the model are discussed. Section IV presents some conclusions and extensions.

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1. Assumptions

The following assumptions are made[1]:

A1. In order to keep the model as simple as possible we assume only one type of resource, R and a production function

$$Q_i = F_i\,(R_i) \tag{1}$$

with $F_i' > 0$, $F_i'' < 0$, $i = 1, 2$.

A2. The production of commodities $i = 1, 2$ generates pollutants $S_i{}^p$ as a joint product.

$$S_i{}^p = H_i\,(Q_i) = H_i\,[F_i\,(R_i)] = Z_i\,(R_i) \tag{2}$$

with $Z_i' > 0$, $Z_i'' \geq 0$.

A3. Resources may also be used for abatement purposes. Let $S_i{}^r$ indicate the quantity of pollutants reduced in Sector i. The abatement function is given by

$$S_i{}^r = F_i{}^r\,(R_i{}^r) \tag{3}$$

with $F_i{}^{r\prime} > 0$, $F_i{}^{r\prime\prime} < 0$.

A4. Net emissions or pollutants ambient in the environment are defined as emissions produced ($S_i{}^p$) minus emissions abated ($S_i{}^r$)

$$S_i = S_i{}^p - S_i{}^r \tag{4}$$

A5. Firms maximize profits and regard commodity prices, factor prices and the emission tax as given. Factor demand conditions are given by

$$\begin{aligned} r &= (p - zH_1')\,F_1'\,(R_1) \\ r &= (1 - zH_2')\,F_2'\,(R_2) \\ r &= zF_i{}^{r\prime}\,(R_i{}^r) \end{aligned} \tag{5}$$

where $p = \tilde{p}_1/\tilde{p}_2$, $r = \tilde{r}/\tilde{p}_2$ and $z = \tilde{z}/\tilde{p}_2$ and $\tilde{p}_i$, $\tilde{r}$, $\tilde{z}$ indicate nominal prices.

A6. The resource can be used for production and abatement and is given

$$R_1 + R_2 + R_1{}^r + R_2{}^r = \bar{R} \tag{6}$$

A7. Income Y is defined from the production side. There are no savings. In order to close the model, we assume that the govern-

[1] For the assumptions of a closed economy compare [11].

ment spends the tax income received in form of transfers to the households. Consequently disposable income of the households is identical to national income at market prices and is defined as

$$Y = pQ_1 + Q_2 \tag{7}$$

A 8. Commodity demand is given by

$$Q_i^D = D_i\,(p, Y) \tag{8}$$

Excess demand is defined as

$$E_i = Q_i^D - Q_i \tag{9}$$

An analogous system of equations holds for the foreign country with a + denoting variables of the foreign country. We assume that no emission tax is levied in the foreign country. This assumption is equivalent to assuming that the foreign country has a high assimilative capacity so that pollutants need not be considered. The foreign country is characterized by equations analogous to (1), (6), (7), (8), (9) and

$$r^+ = pF_1^{+\prime} \tag{5'}$$

$$r^+ = F_2^{+\prime},$$

Since $z^+ = 0$ and consequently $R_i^{r+} = 0$.

The world market for commodity 1 has to be in equilibrium

$$E_1 + E_1^+ = 0 \tag{10}$$

Observe that the budget restraint must hold for the world as a whole and for each individual country. From the budget restraint for the world

$$pE_1 + E_2 + pE_1^+ + E_2^+ = 0$$

we have due to $E_1 + E_1^+ = 0$, that $E_2 + E_2^+ = 0$, i. e. the world market for commodity 2 is in equilibrium. Equilibrium in the world market for commodity 1 ensures equilibrium in the world market for commodity 2 (Walras law) so that an additional equation for equilibrium in the world market for commodity 2 would be redundant.

Note that $pE_1 + E_2 = 0$, i. e. equilibrium in the balance of trade, is not asked for explicitly. From the budget restraint we have $Y = pQ_1^D + Q_2^D = pQ_1 + Q_2$, so that $p\ (Q_1^D - Q_1) + Q_2^D - Q_2 = pE_1 + E_2 = 0$ and the balance of trade is in equilibrium[2].

[2] If $pE_2 + E_2 = 0$ is introduced explicitly in the system of equations, one of the demand functions Q_i^D is redundant.

Consider a reduced system of equations where the emission function (2) and the abatement function (3) are only implicitly taken into account in the factor demand condition. Table 1 summarizes the equations.

Table 1. System of Equations

(1)	$Q_i = F_i(R_i)$	$Q_i^+ = F_i^+(R_i^+)$
	$r = (p - zH_1')\, F_1'(R_1)$	$r^+ = pF_1^{+\prime}(R_1^+)$
(5)	$r = (1 - zH_2')\, F_2'(R_2)$	$r^+ = F_2^{+\prime}(R_2^+)$
	$r = zF_i^{r\prime}(R_i^r)$	
(6)	$\Sigma R_i + \Sigma R_i^r = \bar{R}$	$\Sigma R_i^+ = \bar{R}^+$
(7)	$Y = pQ_1 + Q_2$	$Y^+ = pQ_1^+ + Q_2^+$
(8)	$Q_i^D = D_i(p, Y)$	$Q_i^{D+} = D_i^+(p, Y^+)$
(9)	$E_i = Q_i^D - Q_i$	$E_i^+ = Q_i^{D+} - Q_i^+$
(10)	$E_1 + E_1^+ = 0$	

Table 1 contains 23 equations with the 23 variables Q_i, Q_i^+, R_i, R_i^r, R_i^+, S_i^r, Q_i^D, Q_i^{D+}, E_i, E_i^+, r, r^+ and p.

Due to Jevons law of the indifference of prices we must have a common price in trade equilibrium so that we do not have to distinguish between p and p^+. Factor price, however, may differ between countries[3].

2. The Model

The model can be further reduced to the following system of equations:

$$
\begin{aligned}
&\text{i)} && r = (p - zH_1')\, F_1'(R_1) \\
&\text{ii)} && r = (1 - zH_2')\, F_2'(R_2) \\
&\text{iii)} && r = zF_1^{r\prime}(R_1^r) \\
&\text{iv)} && r = zF_2^{r\prime}(R - R_1^r - \Sigma R_i) \qquad (11) \\
&\text{v)} && r^+ = pF_1^{+\prime}(R_1^+) \\
&\text{vi)} && r^+ = F_2^{+\prime}(\bar{R}^+ - R_1^+) \\
&\text{vii, viii)} && E_i = D_i\,[p, pF_1(R_1) + F_2(R_2)] - F_i(R_i) \\
&\text{ix)} && -E_1 = D_1^+\,[p, pF_1^+(R_1^+) + F_2^+(\bar{R}^+ - R_1^+)] - F_1^+(R_1^+) \\
&\text{x)} && E_2^+ = D_2^+\,[p, pF_1^+(R_1^+) + F_2^+(\bar{R}^+ - R_1^+)] - F_2^+(\bar{R}^+ - R_1^+)
\end{aligned}
$$

[3] Observe that production (emission and abatement) technology may differ between countries.

The system (11) contains ten equations and the ten variables E_i, E_2^+, R_i, R_1^r, R_1^+, r, r^+, p with z being fixed as a policy parameter in the home country.

We now assume a change in the emission tax of the home country and analyze how the variables will change. Differentiating Eq. (11) totally with respect to z and rearranging terms we have[4].

The coefficients are defined as

$$a_i = zH_i'' F_i'^2 - (p_i - zH_i')\, F_i'' = zZ_i'' - p_x F_i'' > 0 \text{ with } p_x \begin{cases} = p \text{ for } i=1 \\ =1 \text{ for } i=2 \end{cases}$$

$$b_1^j = D_{1p}^{j\prime} + D_{1Y}^{j\prime}\, Q_1 < 0^5$$

with j = country I, II,

$$b_2^j = D_{2p}^{j\prime} + D_{2Y}^{j\prime}\, Q_1 > 0^6$$

with j = country I, II.

3. Implications

1. We are interested in the following problem. How does environmental policy in the home country affect the variables of the system? How will environmental policy affect sector structure and the allocation of resources in an open economy? How will the results for a closed economy be changed if trade is introduced? How will environmental policy influence the terms of trade?

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[4] The total derivative of Eq. (11 vii) has been multiplied with p and added to the total derivative of Eq. (11 viii) in order to obtain a new Eq. (11 vii')

$$-(b_2 + pb_1)\, dp + pdE_1 + dE_2 = 0.$$

This yields the seventh line in Eq. (12). Similarly Eq. (11 ix) has been multiplied with p and added to (11 x). This yields the last line in Eq. (12).

[5] This follows from Slutsky's rule. Compare [11].

[6] In a two-commodity model, the two commodities must be subsitutes. Consequently $D_{2p}' > 0$. Also we assume $D_{i'}^{iY} \geq 0$. Also observe that from $Y = pD_1 + D_2$, we have $(pD_{1Y}' + D_{2Y}' - 1)\, dY + (Q_1 + pD_{1p}' + D_{2p}')\, dp = 0$, where the first bracket (Engel aggregation) and the second bracket (Cournot aggregation) are zero. $pb_1 + b_2 = Q_1\,(p\,D_{1Y}' + D_{2Y}') + pD_1p' + D_{2p}' = 0$ (Cournot aggregation). Consequently $b_2 = -pb_1$ and $b_1 < 0 \Rightarrow b_2 > 0$.

$$\begin{bmatrix} a_1 & & & 1 & & & -F_1' & & & \\ & a_2 & & 1 & & & & & & \\ & & -zF_1^{r''} & 1 & & & & & & \\ zF_2^{r''} & zF_2^{r''} & zF_2^{r''} & 1 & & & & & & \\ & & & & -pF_1^{+''} & 1 & -F_1^{+'} & & & \\ & & & & F_2^{+''} & 1 & & & & \\ & & & & & & -b_2-pb_1 & p & 1 & \\ -pD'_{2Y}F_1' & pD'_{1Y}F_2' & & & & & -b_2 & & 1 & \\ & & & & & & -b_2^+-pb_1^+ & -p & & 1 \\ & & & & -p\,[D_{2Y}^{+'}F_1^{+'}+D_{1Y}^{+'}F_2^{+'}] & & -b_2^+ & & & 1 \end{bmatrix} \begin{bmatrix} dR_1 \\ dR_2 \\ dR_1^r \\ dr \\ dR_1^+ \\ dr^+ \\ dp \\ dE_1 \\ dE_2 \\ dE_2^+ \end{bmatrix} = \begin{bmatrix} -Z_1'dz \\ -Z_2'dz \\ F_1^{r'}dz \\ F_2^{r'}dz \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{12}$$

2. As a sufficient condition for a positive determinant we have from Eq. (I) in the appendix

$$D_{iY}^{j\prime} \geq 0 \Rightarrow \Delta > 0 \tag{13}$$

$i = 1, 2$; j = country I, II,

i. e. the two commodities are not inferior in both countries.

3. We have the following results

$$D_{iy}^{j\prime} \geq 0 \Rightarrow \frac{\Sigma\, dRi}{dz} < 0. \tag{14 i}$$

$$\left.\begin{array}{l} D_{iY}^{j\prime} \geq 0 \\ Z_1' > Z_2' \end{array}\right\} \Rightarrow \frac{dR_1}{dz} < 0 \tag{14 ii}$$

$$D_{iY}^{j\prime} \geq 0 \Rightarrow \frac{dR_1^r}{dz} > 0 \tag{14 iii}$$

$$\left.\begin{array}{l} D_{iY}^{j\prime} \geq 0 \\ Z_1' > Z_2' \\ a_2 > a_1 \end{array}\right\} \Rightarrow \frac{dr}{dz} > 0 \tag{14 iv}$$

$$\left.\begin{array}{l} D_{iY}^{j\prime} \geq 0 \\ \\ D'_{2Y} \geq pD'_{1Y} \\ \\ a_2 > a_1 \\ \\ Z_1' > Z_2' \end{array}\right\} \Rightarrow \left\{\begin{array}{l} \frac{dp}{dz} > 0 \\ \\ \frac{dR_1^+}{dz} > 0 \\ \\ \frac{dE_1}{dz} > 0 \\ \\ \frac{dE_2}{dz} < 0 \end{array}\right. \tag{14 v}$$

4. $Z_i' > Z_j'$ is an important condition for many of the results. It means that sector i has a greater marginal tendency to pollute than sector j (per unit of resource used). Reallocating one unit of resource from sector j to sector i then implies an increase in emissions.

It must be assumed that similarly to other factor-intensity conditions the ranking of sectors with respect to the marginal tendency to pollute is not reversed if the variables of the system such as prices change.

The non-reversal condition is fulfilled if we assume that i) $Z_i'(R_i) > Z_j'(R_j)$ for $R_i = R_j$ and that ii) the pollution-intensively producing sector (according to the marginal concept) is not "too" small. The ii-condition reflects the fact that "small is beautiful" and that a potentially polluting sector has a low marginal pollution-intensity below a certain relative size to the other sector (due to the convex emission function). Consider diagram 1 where $Z_1'(R_1) > Z_2'(R_2)$ has been assumed for all $R_1 = R_2$. If sector 2 produces at B, sector 1 is pollution-intensive in the sense of the marginal concept for all $R_1 > R_A$. Assume, however, sector 2 is in C and sector 1 in A. Then the relative size makes sector 2 the pollution-intensively producing sector.

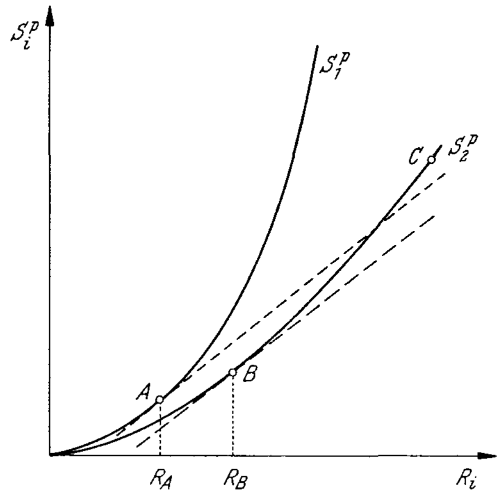

Fig. 1

5. Let $Z_1' > Z_2'$ indicate that sector 1 is the pollution-intensively producing sector. If both commodities are not inferior in both countries, resource use in the pollution-intensively sector of the home country will fall (Eq. 14 ii) and resource use in the abatement activity Sector 1 will increase. Also resource use in both production activities of the home country will decline, whereas resource use in both abatement activities will increase.

In the less pollution-intensively producing sector of the home country it cannot be specified that resource use will decline or increase. The model allows both cases. Thus, in one case Sector 1 and Sector 2 lose resources to the abatement activity, whereas in the second case, Sector 1 loses resources to Sector 2 and the abatement activity.

Since $\Sigma\, dR_i/dz < 0$ and $\Sigma\, dR_i^r/dz > 0$ we know that net emissions in the home country will be reduced and environmental quality will rise.

6. Let us now consider the effect of environmental policy on the terms of trade, exports and imports.

Assume $a_2 \geq a_1$,[7] $Z_1' > Z_2'$ and let the home country export the pollution-intensively produced commodity. Also assume $D_{2Y}' \geq pD_{1Y}'$, i. e. the demand for the pollution-intensively produced commodity is less sensitive to income changes than for commodity 2. Then the terms of trade will improve for the home country that is undertaking environmental policy.

$D_{2Y}' \geq pD_{1Y}'$ ensures that home demand for the pollution-intensively commodity will not fall too strongly. We can establish that real national income will decline. Since $D_{2Y}' \geq pD_{1Y}'$ ensures that home demand for the pollution-intensively produced good will not fall too strongly with declining income for given p and since production quantities of the pollution-intensively produced commodity will decline, quantities available for exports will be reduced.

7. In the every day discussion of environmental policy in an open economy, it is argued that environmental policy reduces the comparative advantage of pollution-intensively producing sectors, that it consequently affects export chances negatively and that it endangers employment in the pollution-intensively producing sectors. From this point of view it is argued that environmental policy should consider these opportunity costs (defined as reduction in achievement levels of policy targets). The basic recommendation of this argument is that environmental policy should be less strict. This argument, however, is based on a mercantilistic motivation of international trade. We here can show that environmental policy of the home country leads to an improvement in the terms of trade under the conditions specified. Moreover, environmental quality is improved. In the everyday discussion the potential positive terms-of-trade effect of environmental policy is not mentioned.

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[7] $a_2 > a_1$: $\left|\frac{dR_1}{dr}\right| > \left|\frac{dR_2}{dr}\right|$ specifies that (for given p and z) Sector 1 is more sensitive to changes in resource price than Sector 2 (Compare H. Siebert [11], p. 10). Under this condition and for $Z_1' > Z_2'$, the resource price will rise, i. e. the price of the resource will rise, if the pollution-intensively producing Sector 1 also heavily depends on the resource used. We can expect that this condition unfolds into a set of factor intensity condition in a multifactor model.

8. In diagram 2 the argument is illustrated geometrically. The concave transformation space[8] of the home country is given by *OADE*. The production block of the foreign country is given by *XYZ*. It is assumed for simplicity that the foreign country does not undertake environmental policy. The initial trade equilibrium is point *F* where the production block of the foreign country is tangent to the transformation space of the home country.

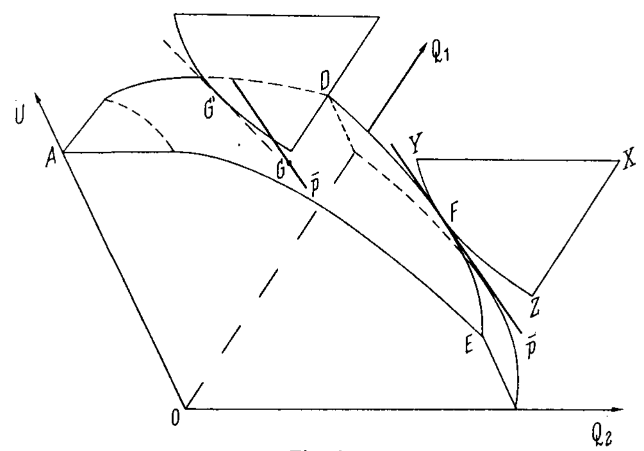

Fig. 2

If the home country increases the emission tax, environmental policy will be improved, and income will be reduced for given $\bar{p}$. This effect is illustrated by a movement from *F* to *G* (the production block of the foreign country is not drawn). The terms of trade effect is illustrated by a movement from *G* to *G'*, so that the overall change stemming from environmental policy can be split into a withdrawal effect and a terms of trade effect. Whereas the withdrawal effect reduces Q_1, ΣR_i, Y and increases ΣR_i^r and improves environmental quality, the terms of trade effect improves the terms of trade and changes sectoral structure in favor of the pollution-intensively produced commodity 1[9]. From our analysis

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[8] On the construction of the transformation space and its properties compare [12].

[9] Note that points *G* and *G'* do not imply the same environmental quality. In our model, environmental policy does not fix an environmental quality standard $\bar{U}$ but sets an emission tax. The movement from *G* to *G'* due to demand conditions in an open economy represents a shift in favor

we know that under the conditions specified, the new trade equilibrium at G' is associated with a smaller production quantity of Q_1 (compared to F), and smaller export and import quantities. The trade triangle associated with point G' (not drawn in the diagram) is smaller than in the original situation F (not drawn). In the foreign country, the new terms of trade require an increased specialization towards commodity Q_1. This is due to the fact that environmental policy in the home country reduces the home country's comparative advantage for its export commodity 1 (which is produced pollution-intensively). Consequently, environmental quality in the foreign country will be reduced.

9. From Eq. (VII) in the appendix, the terms of trade of the home country may worsen if the conditions in (14v) are reversed. Assume the home country exports the environmental friendly produced commodity 1; let commodity 2 be produced pollution-intensively and let Sector 2 be more heavily dependent on the resource. Then environmental policy will worsen the terms of trade of the home country, export quantities will rise and import demand will increase. In this case environmental policy will improve environmental quality, but the terms of trade are reduced.

10. With respect to the effect on real national income measured in terms of commodity 2 two different effects have to be distinguished: i) the withdrawal-effect and ii) the terms-of-trade effect. The withdrawal-effect will reduce national income since resources are withdrawn from production. For given $\bar{p}$, national income will decline. In Eq. (XI) of the appendix, the two last terms are negative if the home country exports the pollution-intensively produced commodity, i. e. the withdrawal effect (for given $\bar{p}$) is negative $\left[\left(\frac{dY}{dz}\right)_{\bar{p}} < 0\right]$. If the home country exports the pollution-intensively produced commodity (and if $a_2 \geq a_1$ and $D_{2Y}' \geq pD_{1Y}'$) the terms of trade effect runs counter to the withdrawal effect. For the change in national income we have

$$\left.\begin{matrix} Z_1' > Z_2' \\ -\mu_{1p} > \alpha > 1 \end{matrix}\right\} \Rightarrow \frac{dY}{dz} < 0$$

$$\text{with } \alpha = \frac{1}{1 - \dfrac{r + zH_1'F_2'}{r + zH_1'F_1'}}$$

of commodity 1, i. e. in favor of the pollution-intensively produced commodity. We consequently can expect a lower environmental quality at point G' (relative to G).

From the Cournot-aggregation[10] we know that

$$\frac{-pD_{1p}'}{Q_1} - \frac{D_{2p}'}{Q_1} = 1$$

and consequently

$$\mu_{1p} - \frac{D_{2p}'}{Q_1} = 1.$$

Since $D_{2p}' > 0$ in a two-commodity model we know that $\mu_{1p} > 1$.

If sector 1 is strongly emission-intensive[11], α is close to unity and the price elasticity of demand does not have to be much above 1 to let national income fall. Apparently, the strong emission-intensity of sector 1 is sufficient for sector 1 to lose large demand quantities. This, in turn, makes sure that the withdrawal effect outweighs the revaluation effect. If, however, sector 1 is only weakly emission-intensive, α is higher than unity, and the demand for the emission-intensively produced commodity must be very elastic for demand quantities to decline. Thus the stronger emission-intensity of the pollution-intensively producing sector the more likely is it that the results will hold.

11. Define[12] real national income Y_1 in terms of the emission-intensively produced commodity 1 with $Y_1 = Q_1 + 1/p\, Q_2$.

Then we have

$$\frac{dY_1}{dz} = \frac{dQ_1}{dz} + \frac{1}{p}\frac{dQ_2}{dz} + Q_2 \frac{d\left(\frac{1}{p}\right)}{dz}$$

Since the first two terms are negative[13] and since $\frac{dp}{dz} > 0$ implies $\frac{d\left(\frac{1}{p}\right)}{dz} < 0$, we can establish that under condition (14v) real national income will fall, if it is measured in terms of the emission-intensively produced commodity.

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[10] Compare M. D. Intriligator, Mathematical Optimization and Economic Theory, Englewood Cliffs 1971, p. 163.

[11] It should be noted that the same condition holds for a decline in income in the autarky case. Compare Siebert [11].

[12] I owe this insight to C. C. von Weizsäcker and an anonymous referee.

[13] Compare equation XI′ in the appendix.

12. In the model presented the emission tax is changed parametrically so that the quadruple (Q_1, Q_2, U, z) indicates output and environmental quality for a given z. An increase in the emission tax will imply benefits and costs. The benefit consists in an improvement of environmental quality. The costs consist in a decline in output of at least one sector, or in a decline of national income. In determining the optimal emission tax, these benefits and costs have to be considered. The optimum is reached where in diagram 2 the three-dimensional social indifference function $\overline{W} = W(Q_1, Q_2, U)$, i. e. an indifference lid, will be tangential to the transformation space, i. e. where marginal benefits and costs of environmental policy are equal.

4. Conclusions and Extensions

Assume the home country exports the pollution-intensively produced commodity. Increasing the emission tax will under a set of conditions reduce the quantity of the pollution-intensively produced commodity and reduce exports (and imports). The terms of trade will improve. Consequently one cannot state that environmental policy will damage the home country. Though exports will be smaller and the export sector will be reduced, the improvement in the terms of trade will be a positive effect on national welfare.

In reality we observe that countries are reluctant to use emission taxes but very often favor a permit system and other administrative devices. The analysis can be extended to such environmental policy instruments. Also trade restrictions may be expected such as product norms, production qualifications.

Finally the model could be extended to analyze the effect of tariffs on pollution-intensively produced commodities and their effect on the trade equilibrium.

Appendix

$$\Delta = DM + F_1' \{z^2 F_1^{r''} F_2^{r''} (D_{2Y}' F_1' + D_{1Y}' F_2') - D_{2Y}' F_1' z (F_1^{r''} + F_2^{r''})\} \tag{I}$$

with

$$D = a_1 [a_2 z(-F_1^{r''} - F_2^{r''}) + z^2 F_1^{r''} F_2^{r''}] + a_2 z^2 F_1^{r''} F_2^{''r} > 0 \tag{I'}$$

$$M = (b_1 + b_1^+)(p F_1^{+''} + F_2^{+''}) + (D^+_{2Y}{}' F_1^+ + D^+_{1Y}{}' F_2^{+'}) F_1^{+'} \tag{I''}$$

$$D_{iY}^{j'} \geq 0 \Rightarrow \begin{cases} M > 0 \\ \Delta > 0 \end{cases} \qquad i = 1, 2; \quad j = \text{I, II}$$

$$\frac{dR_1}{dz} = \frac{1}{\Delta}\{MN - D_{1Y}'F_2'L\} \tag{II}$$

with

$$N = -z^2F_1^{r''}F_2^{r''}(Z_1' - Z_2') + za_2(F_1^{r''} + F_2^{r''})\left(Z_1' + \frac{r}{z}\right) \tag{II'}$$

$$L = zF_1'(pF_1^{+''} + F_2^{+''})(F_1^{r''} + F_2^{r''})\left(Z_2' + \frac{r}{z}\right) > 0 \tag{II''}$$

$$Z_1' > Z_2' \Rightarrow N < 0$$

$$\frac{dR_2}{dz} = \frac{1}{\Delta}\{MP - D_{2Y}'F_1'L\} \tag{III}$$

with

$$P = z^2F_1^{r''}F_2^{r''}(Z_1' - Z_2') + za_1(F_1^{r''} + F_2^{r''})\left(Z_2' + \frac{r}{z}\right) \tag{III'}$$

$$\begin{aligned}\frac{dR_1^r}{dz} = \frac{1}{\Delta}\Big\{&-zF_2^{r''}M\left[a_1\left(Z_1' + \frac{r}{z}\right) + a_2\left(Z_2' + \frac{r}{z}\right)\right] - \\ &-F_1'(D_{1Y}'F_2' + D_{2Y}'F_1')(pF_1^{+''} + F_2^{+''})\left(Z_1' + \frac{r}{z}\right)\Big\}\end{aligned} \tag{IV}$$

$$\begin{aligned}\frac{dr}{dz} = \frac{1}{\Delta}\{&M\,[z^2F_1^{r''}F_2^{r''}(a_2Z_1' - a_1Z_2') - a_1a_2r\,(F_1^{r''} + F_2^{r''})] \\ &-F_1'(pF_1^{+''} + F_2^{+''})\,[z^2F_1^{r''}F_2^{r''}(D_{1Y}'F_2' + D_{2Y}'F_1')\,Z_2' - \\ &- D_{2Y}'F_1'a_2r\,(F_1^{r''} + F_2^{r''})]\}\end{aligned} \tag{V}$$

$$\frac{dR_1^+}{dz} = F_1^{+\prime}K \tag{VI}$$

with

$$\begin{aligned}K = {}& z^2F_1^{r''}F_2^{r''}(D_{1Y}'F_2' + D_{2Y}'F_1')(Z_1' - Z_2') - z\,(F_1^{r''} + F_2^{r''}) \\ &\left[a_2D_{2Y}'F_1'\left(Z_1' + \frac{r}{z}\right) - a_1D_{1Y}'F_2'\left(Z_2' + \frac{r}{z}\right)\right]\end{aligned} \tag{VI'}$$

with[14]

$$\left.\begin{array}{l} D_{2Y}' \geq D_{1Y}'p \\ a_2 > a_1 \\ Z_1' > Z_2' \end{array}\right\} \Rightarrow K > 0$$

$$\frac{dp}{dz} = -(pF_1^{+''} + F_2^{+''})\frac{K}{\Delta} \tag{VII}$$

[14] Observe that $pF_1' > F_2'$ if $Z_1' > Z_2'$. This follows from the factor demand condition.

$$\frac{dE_1}{dz} = \{b_1^+(pF_1^{+''} + F_2^{+''}) + (D_{1Y}^{+'}F_2^{+'} + D_{2Y}^{+'}F_1^{+'})\} \frac{K}{\Delta} \quad \text{(VIII)}$$

$$\frac{dE_2}{dz} = -\{pM + b_2\ (pF_1^{+''} + F_2^{+''})\} \frac{K}{\Delta} \quad \text{(IX)}$$

$$\frac{dE_2}{dz} = -\{(pb_1 + b_2 + pb_1^+)\ (pF_1^{+''} + F_2^{+''}) + pF_1^{+'} (D_{2Y}^{+'}F_1^{+'} + D_{1Y}^{+'}F_2^{+'})\} \frac{K}{\Delta} \quad \text{(X)}$$

$$\left.\begin{matrix} K > 0 \\ \Delta > 0 \end{matrix}\right\} \Rightarrow \frac{dE_2}{dz} < 0$$

$$\frac{dY}{dz} = \frac{1}{\Delta}\{-Q_1\ (pF_1^{+''} + F_2^{+''})\ K + M\ (pF_1'N + F_2'P) - F_1'F_2'L\} \quad \text{(XI)}^{15}$$

$$\frac{dY}{dz_{\bar{p}}} = \frac{1}{\Delta}\{M\ (pF_1'N + F_2'P) - F_1'F_2'L\} < 0 \quad \text{(XI')}$$

$$pF_1'N + F_2'P = (r + zZ_1')\ N + (r + zZ_2')\ P = = r\ (N + P) + z\ (Z_1'N + Z_2'P) \quad \text{(XI'')}$$

$$Z_1' > Z_2' \Rightarrow pF_1'N + F_2'P < 0 \quad \text{(XI''')}$$

Summary

The paper analyzes the problem how environmental policy affects sector structure, the allocation of resources, relative price (and comparative advantage) and national income in a two-country case with varying terms of trade. The frame of reference is a two-sector model in which production generates pollutants as a joint product. If a country exports the pollution-intensively produced commodity environmental policy will improve its terms of trade under suitable conditions with respect to demand. Whereas in the political debate the negative effect of environmental policy on the international competiveness of a country is stressed, the terms-of-trade effect gives more leeway to environmental policy. The effects on output, export, imports and the other variables of the system are discussed.

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15 Eq. (XI) may be restated as $\frac{dY}{dz} = \frac{1}{\Delta}\{(pF_1'N + F_2'P)\ [M - Q_1D_{1Y}'^{+} (pF_1^{+''} + F_2^{+''})] - F_1'F_2'L + Q_1F_1'\ (pF_1^{+''} + F_2^{+''})\ N\}$ where under the conditions assumed only the last term is positive.

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