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Environmental Protection and International Specialization

By

Horst Siebert

Contents: I. Introduction. — II. The Model. — III. Solution and Implications. — IV. Conclusions and Extensions.

I. Introduction

The environment and its relation to the economic system has been a neglected area of economic analysis in the past. Recently, attempts have been made to incorporate environmental problems into economic theory such as growth theory¹, economic policy², spatial planning³ and international trade. The following note discusses the relation of environmental quality management and international trade⁴.

Remark: I acknowledge comments from a referee and Dr. R. Pethig, W. Gretz and W. Vogt.

¹ R. C. d'Arge and K. C. Kogiku, "Economic Growth and the Environment", *The Review of Economic Studies*, Vol. XL, Edinburgh, 1973, pp. 615sq.

² Allen V. Kneese, "Environmental Pollution: Economics and Policy", *The American Economic Review*, Vol. LXI, Menasha, Wisc., 1971, *Papers and Proceedings*, pp. 1555sq.

³ Clifford S. Russell and Walter O. Spofford, Jr., "A Quantitative Framework for Residuals Management Decisions", in: *Environmental Quality Analysis, Theory and Method in the Social Sciences*, Papers from a Resources for the Future Conference, Ed. by Allen V. Kneese and Blair T. Bower, Baltimore, London, 1972, pp. 1155sq. — Horst Siebert, "Environment and Regional Growth", *Zeitschrift für Nationalökonomie*, Bd. XXXIII, Wien, 1973, pp. 1085sq.

⁴ On environmental problems and international trade compare: Ralph C. d'Arge, "Trade, Environmental Controls, and the Developing Economies", in: OECD, *Problems of Environmental Economics*, Record of the Seminar Held at the OECD in Summer 1971, Paris, 1972, pp. 2275sq. — *Idem* and Allen V. Kneese, "Environmental Quality and International Trade", *International Organization*, Vol. XXVI, Madison, Wisc., 1972, pp. 4195sq. — William J. Baumol, *Environmental Protection, International Spillovers and Trade*, Wicksell Lecture Society, Stockholm, 1971. — GATT, *Industrial Pollution Control and International Trade*, GATT Studies in International Trade, No. 1, Geneva, 1971. — Horst Siebert, "Trade and Environment", in: *The International Division of Labour, Problems and Perspectives*, International Symposium, Ed. by Herbert Giersch, Tübingen, 1974, pp. 1085sq. — Ingo Walter, "The Pollution Content of American Trade", *Western Economic Journal*, Vol. XI, Long Beach, Calif., 1973, pp. 615sq. — *Idem*, "Environmental Management and the International Economic Order", New York University Center for International Studies, *Policy Papers*, Vol. V, 1973, No. 3.

Introducing environmental aspects into international economics leads to a set of problems that are far from being solved. The following problems may be distinguished: (1) To what extent does the scarcity or abundance of the environment influence the pattern of trade? (2) Can environmental scarcity or abundance be measured in terms of physical variables such as the spatial extent of river systems or the regenerative capacity of the aquaetic system expressed in tons of biochemical oxygen demand, or must the scarcity of the environment take into account the social demand for environmental goods? (3) Since the environment (i) supplies public consumption goods, (ii) provides basic resources and (iii) serves as a receptor of pollutants, the scarcity or abundance of the environment has to be specified with respect to these three roles. Unfortunately, these different functions represent competing uses of the environment. Depending on the function in question different results will be obtained for international specialization. (4) A country may export its pollutants to the neighbour country (transfrontier pollution) thus creating a comparative production advantage for the polluter and causing a disadvantage for the pollutee¹. (5) Since the environment is a public good (except for the case of supplier of resources), no market price exists. It is used as a free commodity. Consequently a market price cannot be used to express scarcity or relative abundance. Assume abatement costs for reaching given standards or effluent charges serve as an indicator of scarcity. Then the question must be asked whether these political prices are reliable indicators of scarcity. (6) A specific problem is to determine to what extent the pattern of trade between developed and less developed countries will be influenced if environmental quality management is put into effect. Will the development strategies of export diversification and import substitution have to be reconsidered under the new aspect of environmental quality management²? (7) How will environmental policy influence the balance of payments, the terms of trade³, and the exchange rates? (8) Will product qualifications or environmental standards for production procedures serve as a new instrument of administrative trade restrictions⁴? (9) Will the implementation of environmental policy induce international capital movements to countries richly endowed with environmental capacity and

¹ A. D. Scott, "The Economics of International Transmission of Pollution", in: OECD, *Problems of Environmental Economics*, *op. cit.*, pp. 255sq.

² Compare Siebert, "Trade and Environment", *op. cit.*

³ Compare Stephen P. Magee and William F. Ford, "Environmental Pollution, the Terms of Trade and the Balance of Payments of the United States, *Kyklos*, Vol. XXV, Basel, 1972, pp. 101sq.

⁴ GATT, *Industrial Pollution Control and International Trade*, *op. cit.*

will these factor movements create or destroy trade¹? (10) To what extent are the welfare effects of foreign trade altered by taking into consideration that the environment is also an input to consumption processes and that production affects environmental quality?

The following note concentrates on the effect of environmental policy on international specialization. Only the role of the environment as a receptor of pollutants is considered. Section II discusses the basic assumptions of the model. Section III presents the solution and some of the implications. Section IV summarizes some conclusions and points out possible extensions.

II. The Model

According to a well-established condition for trade², a country will export a commodity if it has a comparative price advantage in that commodity. Thus the condition for trade to take place is that the price relation between countries differs before trade

$$\frac{p_1}{p_2} \geq \frac{p_1^+}{p_2^+} \quad (1)$$

with p_1, p_2 denoting the prices of commodities 1 and 2 in country I and p_1^+, p_2^+ indicating variables of the foreign country.

The problem is to show that condition (1) is influenced by environmental policy.

Assume a two-commodity world in which for reasons of simplicity only resource R is used. The production function is given by

$$Q_i = F_i(R_i) \text{ with } F_i' > 0, F_i'' < 0 \quad \text{for } i = 1, 2 \quad (2)$$

with F_i' denoting the first and F_i'' the second derivative.

Also assume that the production of output (Q_i) generates a single pollutant S_i as a joint product

$$S_i = H_i(Q_i) \quad \text{with } H_i' > 0, H_i'' \geq 0 \text{ for } i = 1, 2 \quad (3)$$

¹ The problem of trade creating versus destroying international factor movements was pointed out to me by Herbert Giersch.

² Jagdish Bhagwati, "The Pure Theory of International Trade: A Survey", in: *Surveys of Economic Theory*, Prep. for the American Economic Association and the Royal Economic Society, Vol. II, London, New York, 1965, pp. 233sq. — For other hypotheses than relative price differences compare Helmut Hesse, "Hypotheses for the Explanation of Trade between Industrial Countries, 1953—1970, in: *The International Division of Labour, Problems and Perspectives*, op. cit., pp. 39sq.

with H'_i denoting the first and H''_i the second derivative. $H'_i = \frac{dS_i}{dQ_i}$ may be interpreted as the marginal tendency to pollute while producing one additional unit of output.

Engineering production functions suggest for a set of production procedures (e.g. engines) that output can be increased only with progressively rising inputs (e.g. fuels)¹. Progressively increasing inputs, however, may very well explain $H'_i > 0$. Conceivably, in other cases pollutants are in a constant relation to output for a given production procedure, so that $H'_i = 0$. The case that with increasing output the marginal tendency to pollute will decline for a given technology, i.e. $H''_i < 0$, is ruled out in the following analysis since it can be regarded as rather unlikely².

The quantities of pollutants emitted in sector 1 and 2 define the total quantity of pollutants emitted (S_e).

$$S_e = S_1 + S_2 \quad (4)$$

Environmental quality U is influenced by the quantity of pollutants S ambient in the environment

$$U = U(S) \quad \text{with } U' < 0 \quad \text{and } U'' < 0. \quad (5)$$

Equation (5) is a damage function relating environmental quality in non-monetary terms to ambient quantities of pollutants. It is assumed that environmental quality declines progressively with pollutants increasing³. U' denotes the first, U'' the second derivative of the damage function.

$U' = \frac{dU}{dS}$ is defined as the change in environmental quality caused by one unit of pollutants.

¹ Compare Erich Gutenberg, *Grundlagen der Betriebswirtschaftslehre*, Bd. 1: *Die Produktion*, 19. Aufl., Berlin, Heidelberg, New York, 1972, p. 326.

² On a similar function compare Bruce A. Forster, "A Note on Economic Growth and Environmental Quality", *The Swedish Journal of Economics*, Vol. LXXIV, Stockholm, 1972, p. 282.

³ The problem of measurement is not considered. For Equation (5) one would expect that U and S are measured independently, and that U is not measured in terms of S . Thus U may be expressed in value terms. In the following, however, U is supposed to be measured in physical units. Even if U and S are measured in the same dimensions such as tons of pollutants, Equation (5) could be specified in a very simple case as $U = -S$. With this damage function, it can be shown that $\lambda = z$. Equation (5) could also be interpreted as a specification of an index measuring environmental quality.

An environmental protection agency reduces pollutants by employing resource R . Its "production function" is given by

$$S_r = F_3(R_3) \quad \text{with } F'_3 > 0 \quad \text{and } F''_3 < 0 \quad (6)$$

and S_r indicating the quantity of pollutants reduced. For simplicity it is assumed that the abatement of pollutants does not generate new pollutants.

By definition the ambient concentration (or quantity) of pollutants S is given by the pollutants emitted, S_e , minus pollutants abated by the agency (S_r). Accumulation of non-degradable pollutants over time is not considered. Then

$$S = S_e - S_r \quad (7)$$

The environmental protection agency charges an effluent charge z for a unit of pollutant emitted, S_e , by the two sectors. The agency maximizes its "profit" for a pre-determined quality of the environment \bar{U} that is determined outside the model. It can be assumed that the target variable \bar{U} is found by a social process such as voting and deliberation in legislative bodies¹. Thus the environmental protection agency maximizes the Lagrangean expression

$$\begin{aligned} L_1 = & z S_e - r_3 R_3 + \lambda [U(S) - \bar{U}] \\ & + \lambda_1 [S - S_e + F_3(R_3)] + \lambda_2 [\bar{U} - U] \end{aligned} \quad (8)$$

Maximization of (8) yields the conditions

$$r_3 = z F'_3 \quad (8')$$

$$\text{and } -\lambda U' = z \quad (8'')$$

with λ indicating a scarcity price of the environment².

¹ On models of political decision making with respect to environmental quality compare E. T. Haefele, "Environmental Quality as a Problem of Social Choice", in: *Environmental Quality Analysis*, *op. cit.*, pp. 281-300.

² In the correct interpretation, λ indicates how the value of the objective function changes if \bar{U} increases. Note that in the formulation of the problem in (8iii) λ has the desired characteristics and can be interpreted as a shadow price of the environment. For additional implications of (8iii) compare H. Siebert, "Allokationsaspekte des Umweltproblems", *Wirtschaftswissenschaftliches Studium*, Jg. 3, München, Frankfurt, 1974, H. 2, p. 66.

Alternatively to Equation (8) it can be assumed that the agency maximizes a social welfare function with the arguments Q_1 , Q_2 and U . We then obtain the following Lagrangean expression

$$\begin{aligned}
 L &= W(Q_1, Q_2, U) \\
 &+ \lambda_1 [F_1(R_1) - Q_1] \\
 &+ \lambda_3 [\bar{R} - R_1 - R_2 - R_3] \\
 &+ \lambda_4 [H_1(Q_1) + H_2(Q_2) - S_2] \\
 &+ \lambda_5 [S_e - S - S_r] \\
 &+ \lambda_6 [F_3(R_3) - S_r] \\
 &+ \lambda [U(S) - U] \quad \text{Max!}
 \end{aligned} \tag{8iii}$$

Maximization yields the following conditions

$$\begin{aligned}
 \lambda_1 &= \frac{\partial W}{\partial Q_1} + \lambda_4 H'_1 \\
 \lambda &= \frac{\partial W}{\partial U} \\
 \lambda_3 &= \lambda_1 F'_1 \\
 \lambda_3 &= \lambda_2 F'_2 \\
 \lambda_3 &= \lambda_6 F'_3 \\
 \lambda_4 &= \lambda_5 \\
 \lambda_5 &= \lambda U' \\
 \lambda_6 &= -\lambda_6
 \end{aligned} \tag{8iv}$$

Observe that λ_4 , the shadow price of the pollutant emitted, is negative and that λ_6 , the shadow price of pollutants reduced, is positive. As a result we obtain $\lambda_3 = -\lambda_4 F'_3$ and $\lambda U' = \lambda_4$. Since λ_3 is the shadow price of the resource, λ_4 the shadow price of pollutants and λ the shadow price of the environment, maximization of Equation (8iii) also yields conditions (8') and (8'').

From (8') and (8'') the environmental protection agency will set the effluent charge so that

$$\frac{r_3}{F'_3} = -\lambda U' \tag{8v}$$

Condition (8v) is shown in Figure 1. The expression $-\lambda U'$ shows marginal social damage as the product of environmental deterioration (U') and the evaluation of the environment. Since $U', U'' < 0$, marginal social damage increases progressively if λ does not decline.

The expression $\frac{r_3}{F'_3}$ indicates marginal costs of abatement if an inverse function to the production function of the environmental protection agency exists, i.e. if

$$R_3 = G(S_r)$$

exists. Then by the inverse-function rule

$$G' = \frac{dR_3}{dS_r} = \frac{1}{F'_3}$$

and for a given r_3 the expression $r_3 G' = \frac{r_3}{F'_3}$ represents marginal costs of abatement.

Under the assumptions made, marginal abatement costs will increase. In Figure 1, the x-axis measures the quantity of pollutants ambient in the environment. With an increase in the quantity of pollutants social marginal damage ($-\lambda U'$) increases. Let OA represent a given quantity of pollutants. Moving from A to 0 indicates that pollutants are reduced. Marginal costs of abatement (r_3/F'_3) increase progressively with pollutants reduced. According to (8v) the agency sets the price so that marginal social damage is equal to marginal abatement costs¹. The effluent charge BC minimizes total costs for society².

From (8') we have, for a change in the factor demand of the environmental protection agency,

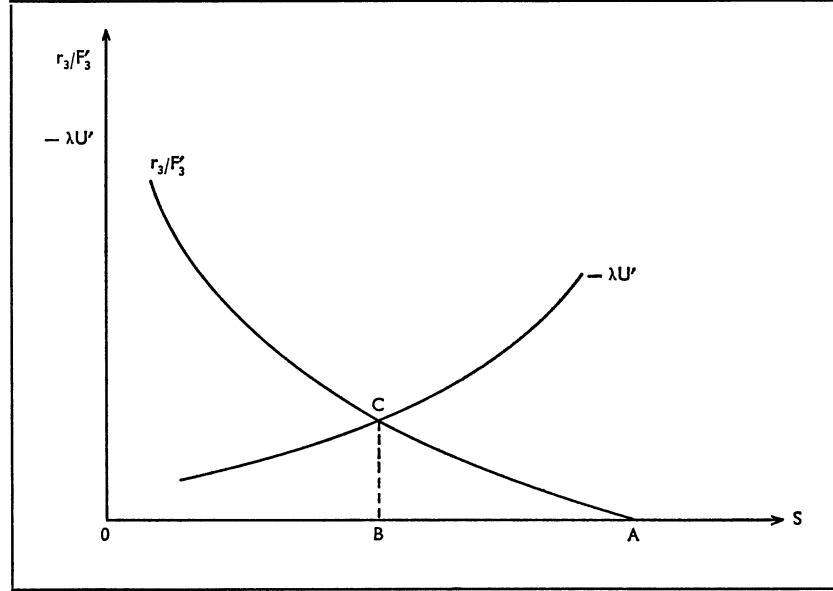
$$dR_3 = \frac{dr_3 - dzF'_3}{z F'_3} \quad (9)$$

Equation (9) defines a change in the resource demand of the environmental protection agency as being dependent on variations of the resource

¹ It should be pointed out that the marginal social damage curve shifts with a change in λ , the scarcity price of the environment. This can be seen from Equation (10) λ itself will change with \bar{U} , the pre-determined level of environmental quality.

² Horst Siebert, *Das produzierte Chaos, Ökonomie und Umwelt*, Stuttgart, 1973, p. 127.

Figure 1



price and of the effluent charge. Since $F_3'' < 0$ resource demand of the agency declines with an increase of the resource price and a lowering of the effluent charge.

From (8'') we obtain, for a change in the effluent charge,

$$dz = -d\lambda U' - \lambda U'' dS \quad (10)$$

Since $U', U'' < 0$, the effluent charge increases with a higher evaluation of the environment ($d\lambda > 0$) and an increase in pollutants ambient in the environment ($dS > 0$).

Resource demand by entrepreneurs is obtained from maximizing the following expression

$$L_2 = p_i Q_i - r_i R_i - z S_i - \lambda_2 [Q_i - F_i(R_i)] - \lambda_3 [S_i - H_i(Q_i)] \quad (11)$$

This yields

$$r_i = p_i F_i' - z H_i' F_i' \quad (11')$$

With the introduction of environmental protection into the system payment to the resource R is reduced by the effluent charge paid per unit of the resource used. Alternatively, Equation (11') indicates that

the commodity price includes two cost elements: factor earnings and the effluent charge. From (11') we obtain profit maximizing resource demand of entrepreneurs with

$$dR_i = \frac{1}{a_i} (dr_i - F'_i dp_i + H'_i F'_i dz) \quad (11'')$$

where

$$a_i = F''_i (p_i - zH'_i) - z F'^2_i H''_i$$

Since $H''_i \geq 0$, $F''_i < 0$, $a_i < 0$, if $p_i > zH'_i$. $p_i \leq zH'_i$ can be ruled out since it would imply negative profits. Consequently, $a_i < 0$. Equation (11'') specifies the change in demand for resource R by sector 1 and 2 as a function of variations in the resource price, the commodity price and the effluent charge. Entrepreneurial demand for R increases with a falling resource price, with a lowering of the effluent charge and a rising commodity price.

Assume that the resource R is fixed so that

$$dR_3 = -dR_1 - dR_2 \quad (12)$$

Finally, equilibrium on the commodity market requires that

$$Q_i (p_1/p_2) - F_i (R_i) = 0 \quad (13)$$

or assuming that initial commodity prices are set equal to 1, that

$$J'_i dp_1 - J'_i dp_2 - F'_i dR_i = 0 \quad (13')$$

$$\text{with } J'_1 = \frac{\partial Q_1}{\partial (p_1/p_2)} < 0 \text{ and } J'_2 = \frac{\partial Q_2}{\partial (p_1/p_2)}$$

denoting derivatives. If $J'_2 > 0$, products are substitutive; if $J'_2 < 0$, products are complementary.

III. Solution and Implications

Assuming that with perfect mobility in the resource market the price of the resource will be identical in the three uses, so that $dr_1 = dr_2 = dr_3 = dr$, we obtain by substitution the following system of equation:

$$\begin{bmatrix} J'_1 & -J'_1 & -F'_1 & 0 & 0 & 0 \\ J'_2 & -J'_2 & 0 & -F'_2 & 0 & 0 \\ F'_1 & 0 & a_1 & 0 & -1 & -H'_1 F'_1 \\ 0 & F'_2 & 0 & a_2 & -1 & -H'_2 F'_2 \\ 0 & 0 & -zF'_3 & -zF'_3 & -1 & F'_3 \\ 0 & 0 & -\lambda U'' H'_1 F'_1 & -\lambda U'' H'_2 F'_2 & 0 & -1 \end{bmatrix} \cdot \begin{bmatrix} dp_1 \\ dp_2 \\ dR_1 \\ dR_2 \\ dr \\ dz \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ d\lambda U' \end{bmatrix} \quad (14)$$

Equation (14) shows the effects of environmental policy on commodity prices, resource demand, resource earnings and the effluent charge. It should be pointed out that Equation (14) represents a partial equilibrium analysis. Due to the restrictive demand function in which quantity demanded depends only on relative commodity prices but not on income, the model is not closed with respect to resource earnings, profit and income¹.

The model is also partial in the sense that it only considers the role of the environment as a receptor of pollutants. Introducing the consumption aspect of the environment would imply to specify a demand function for the public good environment. Implicitly, this demand aspect is reflected in λ in Equation (8).

Finally, it should be remembered that the model analyzes the effects of environmental policy on the conditions for trade. It does not study problems of trade equilibrium, balance of payments questions and the determination of the terms of trade by international demand.

From Equations (11') and (8'') we obtain for the relation of commodity prices

$$\frac{p_1}{p_2} = \frac{F'_2 (r - \lambda U' H'_1 F'_1)}{F'_1 (r - \lambda U' H'_2 F'_2)} \quad (15)$$

or

$$\frac{p_1}{p_2} = \varnothing(\lambda) \quad (15')$$

Relative commodity prices depend on environmental scarcity. Specifying Equation (15') will allow us to express the condition for trade (Equation 1) in terms of environmental scarcity.

¹ For a similar problem compare Charles E. McLure, Jr., "Taxation, Substitution, and Industrial Location", *The Journal of Political Economy*, Vol. LXXVIII, Chicago, Ill., 1970, pp. 1128-1134. — Observe, that the demand price p_i in (14) and the scarcity price λ_i in (8iv) are not identical. Observe, however, that if $\partial W / \partial Q_i = p_i$, the definition of λ_i in (8iv) is consistent with (11'). Since $-z = \lambda_4$ and r_i / F'_i represents marginal costs of production, (11') can be interpreted in terms of the definition of λ_i .

We obtain for

$$\frac{d(p_1/p_2)}{d\lambda U'} = \frac{F'_1 F'_2 \{F'_3 (F'_2 - F'_1) + F'_1 F'_2 (H'_1 - H'_2)\}}{D} \quad (15'')$$

with

$$\begin{aligned} D = & -\lambda_2 U'' F'_1 F'_2 (-J'_1 H'_1 - J'_2 H'_2) [F'_3 (F'_2 - F'_1) \\ & + F'_1 F'_2 (H'_1 - H'_2)] - z F'_3 (F'_2 - F'_1) (-J'_1 F'_2 - J'_2 F'_1) \\ & + J'_1 a_1 F'^2_2 - a_2 J'_2 F'^2_2 + F'^2_1 F'^2_2 \end{aligned} \quad (15''')$$

Equation (15'') specifies the effect of a change in the scarcity price of the environment on the price relation of the commodities. As U'' , a_1 , a_2 , J'_1 , $F'_3 < 0$ by assumption, D_1 , $D > 0$, if as sufficient conditions

$$\begin{aligned} F'_2 & > F'_1 & (i) \\ H'_1 & > H'_2 & (ii) \\ -J'_1 H'_1 & > J'_2 H'_2 & (iii) \\ -J'_1 F'_2 & > J'_2 F'_1 & (iv) \end{aligned} \quad (16)$$

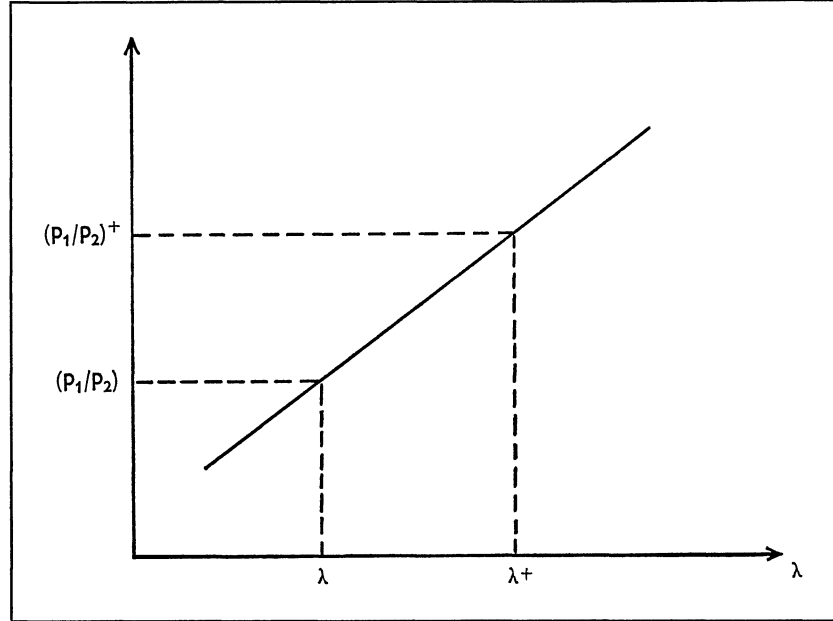
If (i) and (ii) hold, (iii) and (iv) can be expressed as

$$-J'_1 > J'_2 \quad (v)$$

Observe that J'_1 , J'_2 are derivatives with respect to relative prices. Assume commodities 1 and 2 are complementary. Then $J'_2 < 0$, and (v) holds since $-J'_1 \geq 0$. If products 1 and 2 are substitutive, (v) holds as long as the demand for commodity 2 is less sensitive with respect to relative prices than the demand for commodity 1. A low J'_2 indicates a weak substitutive relationship between the two commodities. Conditions (i), (ii) and (v) specify, that the price relation p_1/p_2 increases with the introduction of environmental policy if sector 1 is less productive, if it generates more pollutants per unit of output and if demand cannot shift to the second commodity due to weak substitution possibilities.

As a result we obtain, that the price relation p_1/p_2 increases with λ under the assumptions made. The function $p_1/p_2 = \varnothing(\lambda)$ is shown in Figure 2.

Figure 2



Assume countries I and II have different scarcity prices for the environment, such as λ for country I and λ^+ for country II. Then from $\lambda < \lambda^+$ it follows

$$P_1/P_2 < P_1^+/P_2^+$$

Country I has a lower scarcity price for the environment, i.e. the environment is relatively abundant in country I. Commodity 1 has a high marginal tendency to pollute, i.e. it is produced intensively with respect to the environment. As a result we obtain, that country I has a relative price advantage in commodity 1 and will export that good. Or: *The country richly endowed with the environment will export the commodity with a high pollution content.*

The change in relative commodity prices is accompanied by variations in the other variables of the system. Assume, commodity 1 is produced with a higher marginal pollution content and the other conditions in (16) hold. Then resource use in sector 1 will decline. Since $J'_1 < 0$, this follows from

$$\frac{dR_1}{-d\lambda U'} = \frac{J'_1 F'_2 [F'_3 (F'_2 - F'_1) + F'_1 F'_2 (H'_1 - H'_2)]}{D} \quad (17)$$

Introducing an effluent charge will increase costs in sector 1 and will lead to a reduction in factor use.

For the same conditions factor use will increase in sector 2 as long as $J'_2 > 0^1$. This follows from

$$\frac{dR_2}{-d\lambda U'} = \frac{J'_2 F'_1 [F'_3 (F'_2 - F'_1) + F'_1 F'_2 (H'_1 - H'_2)]}{D} \quad (18)$$

Finally, the effluent charge z increases with the scarcity price λ for the conditions specified².

$$\begin{aligned} \frac{dz}{-d\lambda U'} = \frac{1}{D} \{ & (F'_2 - F'_1) - dz F''_3 (-J'_1 F'_2 - J'_2 F'_1) \\ & + J'_1 a_1 F'^2_2 + F'^2_1 F'_2 - J'_2 a_2 F'^2_1 \} \end{aligned} \quad (19)$$

IV. Conclusions and Extensions

The model shows that relative price differences between countries depend on environmental scarcity or abundance. If the environment is introduced into economic analysis, relative commodity prices are not only determined by relative marginal productivities, but according to Equation (15) depend on the following factors:

- (1) the marginal tendency to pollute of the sector under consideration;
- (2) the marginal social damage caused by one unit of pollutant with the marginal damage being expressed in non-monetary terms.

Marginal social damage depends (i) on the quantity of pollutants generated by production, (ii) on the natural endowment with assimilative capacity, and (iii) on capital outlays (a) for the reduction of pollutants or (b) the augmentation of the assimilative capacity of the environment.

¹ For the resource use in sector 3 we have from Equation (12)

$$dR_3 = \frac{-d\lambda U'}{D} (-J'_1 F'_2 - J'_2 F'_1) [F'_3 (F'_2 - F'_1) + F'_1 F'_2 (H'_1 - H'_2)]$$

² The change in the resource price is given by

$$dr = \frac{-d\lambda U'}{D} \{ F'_3 F'_2 [J'_1 a_1 - J'_2 a_2 + F'^2_1] + z F'_1 F'_2 F''_3 [(H'_1 - H'_2) (-J'_1 F'_2 - J'_2 F'_1)] \}$$

The first bracket is positive, the second is negative due to $F''_3 < 0$ for conditions (16). A sufficient condition for $dr > 0$ is

$$F'_3 [J'_1 a_1 - J'_2 a_2 + F'^2_1] > -z F'_1 F''_3 (H'_1 - H'_2) (J'_1 F'_2 - J'_2 F'_1)$$

- (3) The evaluation of one unit of the environment. The evaluation of the environment depends both on the quantity of environmental services supplied (i.e. natural endowment) and the social demand for these services. Since the environment can be employed for competing uses, the demand for environmental services includes demand for assimilative services and for consumption purposes. Demand for assimilative services depends on the level and technology of consumption and production. Demand for the environment as a public consumption good is a function of the level of income, societal preferences, and the set of (substitutive or complementary) private goods available to the consumer.

All these factors define comparative advantage in terms of environmental abundance or scarcity. In the model presented, abundance or scarcity is measured by the shadow price λ with $H'_1 > H'_2$ describing the technology of pollution.

The model could be extended by treating λ as an endogenous variable and explaining λ by demand and supply functions of environmental services. This would imply to specify the supply of environmental commodities with respect to competing uses, such as the magnitude of public consumption goods, the assimilative capacity of the environment and the trade-off between these competing supply quantities. Also, a demand function for the different environmental commodities (the environment as a consumption good, as a receptor of pollutants) would have to be introduced.

Finally the model could be extended to determine terms of trade, balance of payments and exchange rate effects of a change in environmental policy. This approach would take as a starting point that for equilibrium, world excess demand for the two commodities must be zero and that a balance of payments restraint must be met. By linking relative commodity prices to environmental scarcity λ , λ^+ in the two countries, the effects of changes of the scarcity price on the variables of the model can be analyzed.

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Zusammenfassung: Umweltschutz und internationale Arbeitsteilung. — Der Artikel untersucht die Relevanz der Ausstattung mit dem Faktor Umwelt und die Auswirkungen der Umweltpolitik für die internationale Arbeitsteilung. In einem Zwei-Sektoren-Modell mit einem Produktionsfaktor und der Umwelt als Aufnahme-medium der anfallenden Schadstoffe werden die Bedingungen für internationalen Handel auf die Knappheit der Umwelt zurückgeführt. Es wird unterstellt, daß Schadstoffe als Kuppelprodukte produziert werden, wobei progressiv steigende Schadstoffmengen mit zunehmendem Produktionsniveau zugelassen werden. Das Modell zeigt, daß das reichlich mit Umwelt ausgestattete Land das schadstoffinten-

sive Produkt exportiert. Anhand dieses Modells wird untersucht, wie sich mit einer Verknappung der Umwelt die Variablen des Systems, und zwar die Güter- und Faktorpreise, der Faktoreinsatz und die Gebühr pro Schadstoffeinheit, ändern.

Es wird weiter angenommen, daß eine Umweltbehörde eine Gebühr je Schadstoffeinheit erhebt sowie die Beseitigung der Schadstoffe übernimmt.

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Résumé: La protection de l'environnement et la spécialisation internationale. — L'article examine l'importance de la dotation en facteur environnement ainsi que les effets d'une politique de la protection de l'environnement sur la spécialisation internationale. Après avoir construit un modèle, qui comprend deux secteurs, un facteur de production et l'environnement comme médium absorbant les nuisances, l'auteur exprime les conditions de l'échange international en termes de la rareté de l'environnement. Il est supposé que les produits polluants sont des produits conjoints du processus de production et qu'une autorité publique percevoit une charge financière par unité de produits polluants pour financer l'élimination des biens polluants. D'après le modèle, c'est le pays disposant en abondance d'environnement qui exporte des biens dont leur production cause beaucoup de biens polluants. Ensuite, l'auteur analyse les effets d'une variation dans la rareté de l'environnement sur les variables du modèle élaboré, telles que les prix relatifs des biens, le prix du facteur, l'emploi des ressources et la charge financière.

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Resumen: Protección del medio ambiente y división internacional de trabajo. — El objetivo de este artículo es analizar tanto la relevancia de estar dotado del factor medio ambiente como el impacto de una política de medio ambiente para la división internacional de trabajo. En un modelo con dos sectores y un factor de producción así como el medio ambiente para absorber la polución, se especifican las condiciones para el comercio internacional dada la escasez de medio ambiente. Se supone que la polución surge en el marco de producción compuesta, aumentando su cantidad de forma progresiva con el incremento del nivel de producción. El modelo demuestra que el país relativamente bien dotado de medio ambiente exporta el producto intensivo en polución. Mediante este modelo se analiza cómo la escasez de medio ambiente altera las variables del sistema, concretamente los precios de productos y factores así como la asignación de recursos y el gasto por unidad de polución. Se supone que un organismo público impone arbitrios sobre la generación de polución y se hace cargo de descontaminar el medio ambiente.