Open access • Journal Article • DOI:10.1007/BF01289466

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Published on: 01 Sep 1974

Topics: Comparative advantage and Public finance

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Article — Digitized Version

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Zeitschrift für Nationalökonomie

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Suggested Citation: Siebert, Horst (1974) : Comparative advantage and environmental policy: A note, Zeitschrift für Nationalökonomie, ISSN 0044-3158, Springer, Wien, Vol. 34, Iss. 3/4, pp. 397-402

This Version is available at:
http://hdl.handle.net/10419/3516

Zeitschrift für Nationalökonomie 34 (1974), 397—402

Miszellen

Comparative Advantage and Environmental Policy: A Note

By

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(Received May 30, 1974)

The environment and its relation to the economic system has been neglected by traditional economic theory. Except for the area of welfare economics attempts to introduce environmental aspects into economic analysis are of a rather recent origin. The following note discusses the environment as a determinant of trade[1]. In section I a partial equilibrium model is developed which relates comparative advantage to environmental policy. Section II discusses the solution and implications of the model.

I. The Model

International trade theory starts from the condition for trade

$$\frac{p_1}{p_1^+} \gtrless \frac{p_2}{p_2^+}. \tag{1}$$

[1] Compare R. C. d'Arge and A. V. Kneese: Environmental Quality and International Trade, International Organization, *26* (1972), pp. 419—465; W. I. Baumol: Environmental Protection, International Spillovers and Trade, Stockholm 1971; I. Walter: The Pollution Content of American Trade, Western Economic Journal *XI* (1973), pp. 61—70; S. P. Magee and W. F. Ford: Environmental Pollution, the Terms of Trade and the Balance of Payments of the United Staates, Kyklos *XXV* (1972), pp. 101—118; H. Siebert: Trade and Environment, in: The International Division of Labour. Problems and Perspectives, Ed. by H. Giersch, Kiel 1974, pp. 108—121.

with p_1, p_2 indicating commodity prices, and + labelling variables of the foreign country[2].

Country I exports commodity 1, if the relative price of commodity 1 before trade is lower in country I than in country II. In international trade theory condition (1) is expressed in terms of other economic variables such as factor endowments, production functions, demand functions and other variables (infrastructure, taxation, market forms, ect.). One of the variables influencing the relative prices before trade is the environment.

The environment has three functions for the economic system: (1) it provides consumption goods such as air, water, and amenities of the landscape, (2) it supplies resources for production activities such as raw materials and (3) it receives pollutants that are the result of economic activities. In the following we want to concentrate on the role of the environment to absorb pollutants.

It can be expected that the relative abundance or scarcity of assimilative capacities of the environment differs between countries. First, the natural endowment with environmental capacities being measured in terms of physical factors such as the extent of water systems of the *BOD*-capacity of degradation of organic wastes may be different between countries. Secondly, the evaluation of environmental commodities may vary between countries due to differences in national income per capita and preference schedules. Thus, for a given assimilative capacity in two countries, the country putting less weight on environmental services will have a higher assimilative capacity. Thirdly, the relative abundance or scarcity of environmental services is influenced by the demand for the assimilation of pollutants from production and consumption. Finally, the assimilative capacity may be influenced by public investment[3].

Assume an economy with two commodities and for simplicity a single resource R. The production functions may be characterized by $F'(R_1) > 0$ and $F''(R_1) < 0$. Assume that the production of the two commodities generates a single pollutant, so that

$$S_i = H_i\,[Q_i\,(R_i)] \qquad \text{with } H_i' > 0 \text{ and } H_i'' > 0 \tag{2}$$

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[2] In a world with different currencies the original condition is

$$p_1/p_1^+ \gtrless w \gtrless p_2/p_2^+$$

It can be shown that for freely fluctuating exchange rates and with commodity trade as the only form of international interaction (e. g. no capital movements), this condition can be specified in terms of relative price advantages only. Compare H. Siebert: Außenhandelstheorie, Stuttgart 1973, p. 7.

[3] Examples are instream aeration, water dams to increase water levels during arid seasons, and capital outlays for the treatment of all sorts of pollutants.

The pollution function[4] may be made plausible with an engineering production function in which inputs have to be increased progressively to get additional units of output. Also, $H_i'' > 0$, if S is interpreted not as the emission but as a pollutant. $H_i'' > 0$ may than be explained by the fact that the assimilative capacity of the environment is limited, and once the assimilative capacity is surpassed the self-regenerating forces of the environment may be destroyed and emissions having been degraded so far can no longer be absorbed. Also, interaction between substances may create new pollutants motivating $H_i'' > 0$.

Equilibrium on the commodity markets requests

$$Q_i^D (p_1, p_2) - Q_i^S (R_i) = 0 \tag{3}$$

with Q_i^D quantity demanded and Q_i^S quantity supplied. (3) yields the following conditions for equilibrium

$$\gamma_{11}' \, dp_1 + \gamma_{12}' \, dp_2 - F_1' \, dR_1 = 0 \tag{4}$$

$$\gamma_{21}' \, dp_1 + \gamma_{22}' \, dp_2 - F_2' \, dR_2 = 0 \tag{5}$$

with γ_{ij}' denoting partial derivates of quantities i demanded with respect to prices j.

Factor demand can be derived from a condition for the profit maximum of the individual sector. Assume an effluent charge z is levied per unit of pollutant[5]. Then the profit maximum for sector 1 is given by the maximum of the Lagrangean function

$$L_1 = p_1 Q_1 - r_1 R_1 - z S_1 + \lambda_1 [Q_1 - F_1 (R_1)] + \lambda_2 [S_1 - H_1 (R_1)] \text{ Max!} \tag{6}$$

This yields the following condition

$$p_1 = \frac{r_1 + z H_1' F_1'}{F_1'} \tag{7}$$

From (7) we have

$$a \, dR_1 = dr_1 - F_1' \, dp_1 + H_1' F_1' \, dz \tag{8}$$

with

$$a = [F_1'' (p_1 - z H_1') - z F_1'^2 z H_1''] < 0, \text{ since } p_1 \geqq z H_1'.$$

$p_1 < z H_1'$ would imply that the effluent charge per unit of output exceeds the commodity price.

Eq. (8) can be interpreted as the demand function of entrepreneurs for the resource R. Since $a < 0$, the demand for the resource increases ($dR_1 > 0$) with a falling factor price, a rising commodity price and a lowering of the effluent charge.

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[4] Compare B. A. Forster: A Note on Economic Growth and Environmental Quality, Swedish Journal of Economics 47 (1972), pp. 281—285.

[5] On effluent charges compare the work of Allen V. Kneese, e. g. A. V. Kneese and B. T. Bower: Managing Water Quality: Economics, Technology and Institutions, Baltimore 1968.

A similar equation holds for the factor demand of sector 2

$$b\,dR_2 = dr_2 - F_2'\,dp_2 + H_2'\,F_2'\,dz \tag{9}$$

with b being defined similarly as a.

The factor supply in sector (1) may be determined by

$$R_1 = g\,(r_1/r_2) \tag{10}$$

with

$$dR_1 = g'\,dr_1 - g'\,dr_2 \tag{11}$$

for given initial factor prices $r_1 = r_2 = 1$.

Finally, the total supply of resource R in the economy is given so that

$$dR_2 = -\,dR_1. \tag{12}$$

In (4), dR_1 indicates the change in the input used. In (8) it denotes the change in demand for the input. In (10) it stands for a change in supply. Equating dR_1 in (4), (8) and (11) implies equilibrium in the factor market in sector 1. A similar consideration holds for dR_2 with respect to (5), (9) and (12).

The model used is a partial equilibrium model since some important variables are not included in the system. Thus the demand function does not take into consideration changes in income that might result from the implementation of an effluent charge. Also, the system is not closed with respect to government activities. The effluent charges paid by polluters represent income to the government. It is assumed that the use of these proceeds is "neutral" with respect to the variables of the system[6].

II. Solution and Implications

Eqs. (4), (5), (8), (9), (11) and (12) represent a system of 6 equations with the 6 variables dp_1, dp_2, dr_1, dr_2, dR_1, dR_2. Substitution leads to the following system of equations:

$$\begin{bmatrix} \gamma_{11}' & \gamma_{12}' & -F_1' & & \\ \gamma_{21}' & \gamma_{22}' & +F_2' & & \\ F_1' & & a & -1 & \\ & F_2' & -b & & -1 \\ & & 1 & -g' & g' \end{bmatrix} \begin{bmatrix} dp_1 \\ dp_2 \\ dR_1 \\ dr_1 \\ dr_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ H_1'\,F_1'\,dz \\ H_2'\,F_2'\,dz \\ 0 \end{bmatrix} \tag{13}$$

For the change in commodity prices we have

$$dp_1 = D_1/D \tag{14}$$

with

$$D_1 = g'\,dz\,[H_1'\,F_1' - H_2'\,F_2']\,[-\gamma_{12}'\,F_2' - \gamma_{22}'\,F_1'] \tag{14'}$$

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[6] For a similar problem compare Ch. E. McLure, Jr.: Taxation, Substitution, and Industrial Location, Journal of Political Economy 78 (1970), p. 114/115. With respect to government activity the model can be closed by introducing an environmental policy agency that uses the proceeds for improving the quality of the environment.

and

$$D = [1 - g'(a+b)] [\gamma_{11}' \gamma_{22}' - \gamma_{21}' \gamma_{12}'] + \\ + g' \{F_1' [-\gamma_{12}' F_2' - \gamma_{22}' F_1'] + F_2' [-\gamma_{11}' F_2' - \gamma_{21}' F_1']\} \quad (14'')$$

and

$$dp_2 = D_2/D \quad (15)$$

with

$$D_2 = g' \, dz \, [H_2' F_2' - H_1' F_1'] [-\gamma_{11}' F_2' - \gamma_{21}' F_1'] \quad (15')$$

Setting initial prices equal to 1, and assuming for simplicity that derivatives $\gamma_{ij}' = 0$ if $i \neq j$ we have for the change in relative prices as a reaction to a change in the effluent charge

$$\frac{d(p_1/p_2)}{dz} = \frac{g' [H_1' F_1' - H_2' F_2'] [-\gamma_{11} F_2' - \gamma_{22}' F_1']}{[1 - g(a+b)] [\gamma_{11}' \gamma_{22}'] + g' [-\gamma_{11}' F_2'^2 - \gamma_{22}' F_1'^2]} \quad (16)$$

or since $\gamma_{ij}' < 0$ for $i = \gamma$

$$\frac{d(p_1/p_2)}{dz} \gtrless H_1' F_1' \gtrless H_2' F_2' \quad (16')$$

if $g' > 0$, i. e. if capital is sensitive to a change in relative factor prices.

For $F_1' > F_2'$, the relative price of commodity 1 will increase, if $H_1' > H_2'$, that is if the production of commodity 1 has a higher marginal tendency to pollute than commodity 2.

The change in commodity prices is acconpanied by shifts in the allocation of the resource R between the two sectors and by changes in the factor prices. For $H_1' > H_2'$, the use of resource R in sector 1 will decline[7]. Also the relative factor reward will fall[8].

In Fig. 1 the relative price of commodity 1 is shown as a function of an effluent charge z for a single pollutant S. Assuming $F_1' > F_2'$ and $H_1' > H_2'$ the relative price of commodity 1 will increase with z.

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[7] For the change in factor use in sector 1 we have $dR_1/dz = D_3/D$ with

$$D_3 = -g' [H_1' F_1' - H_2' F_2'] [\gamma_{11}' \gamma_{22}' + \gamma_{21}' \gamma_{12}']$$

and consequently

$$dR_1 \gtrless 0 : H_1' F_1' \gtrless H_2' F_2'.$$

For identical marginal productivities in both sectors, the quantity of the resource R being allocated to sector 1 will decline if the marginal tendency to pollute of sector 1 is higher than that of sector 2.

[8] For the change in factor prices we have $dr_1 = D_4/D$ with

$$D_4 = dz \, \{[\gamma_{11}' \gamma_{22}' - \gamma_{21}' \gamma_{12}'] [g' H_2' F_2' a - H_1' F_1' (a - g' b)]\} \\ - g' F_1' F_2' [H_2' (-\gamma_{12}' F_2' - \gamma_{22}' F_1') + H_1' (-\gamma_{11}' F_2' - \gamma_{21}' F_1')].$$

Assume $\gamma_{ij}' = 0$ for $i \neq j$. Since D_4 is negative unless both H_1' and $H_2' = 0$, the factor reward will decline in sector 1. Even if $H_1' = 0$, r_1 will decline. Due to $H_2' > 0$, r_2 declines. Then due to Eqs. (10) and (11) a larger quantity

According to (16′) price differentials before trade according to condition (1) can be attributed to differences in environmental policy in the two countries. International differences in effluent charges may be due to differences in environmental endowments or due to differences in the evaluation

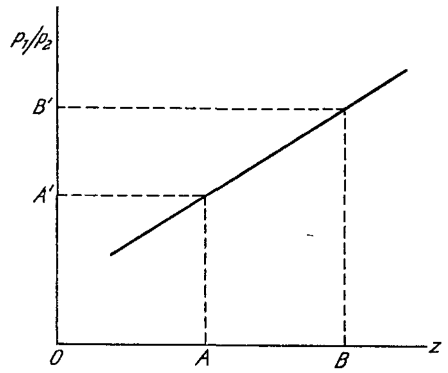

Fig. 1

of environmental quality. Assume country I has a lower absorptive capacity and/or a lower preference for environmental quality. Country I may levy an effluent charge OA. This implies a price ratio OA'. Country II may be less richly endowed with environmental capacity and/or may put a higher value on environmental quality charging an effluent charge OB. This leads under the assumptions made to a higher relative price of commodity 1. As a result we obtain an application of the Heckscher-Ohlin implication. If relative scarcity or abundance is measured both in terms of absorptive capacity and preference for environmental quality the country richly endowed with environmental capacity exports the commodity that is produced with a high marginal tendency to pollute.

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of the resource will be supplied in sector 1. The increase in supply will cause a decline of r_1.

For the relative change of factor rewards we have

$$\frac{d(r_1/r_2)}{dz} = (\gamma_{11}'\gamma_{22}' - \gamma_{21}'\gamma_{12}')(H_2' F_2' - H_1' F_1')$$

consequently, the relative factor reward in sector 1 will fall, if $H_1' > H_2'$.