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## Environmental policy, the gains from trade and the double dividend debate

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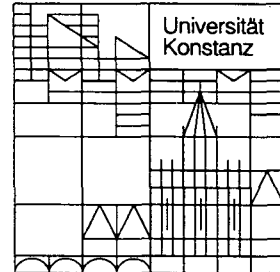
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**Sonderforschungsbereich 178**  
**„Internationalisierung der Wirtschaft“**

Diskussionsbeiträge

Juristische  
Fakultät

Fakultät für Wirtschafts-  
wissenschaften und Statistik

Albert G. Schweinberger

**Environmental Policy, the Gains from  
Trade and the Double Dividend Debate**

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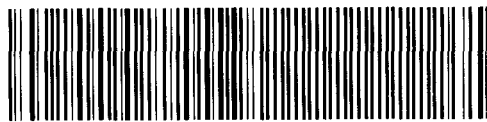
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**Environmental Policy, the Gains from Trade  
and the Double Dividend Debate\***

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**Albert G. Schweinberger**

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## **Abstract**

A multihousehold economy with production/consumption externalities, environmental taxation, and governmental production of pure, nonexclusive and nonrivalrous public goods is assumed. The production of public goods is financed from environmental tax revenue. Globally valid necessary and sufficient conditions for gains from international trade are derived and interpreted. A simple yet general environmental policy rule ensuring trade gains is put forward. The effect of international trade on the personal distribution of income of households is also considered. If the simple policy rule is followed, it is shown that the move to free trade represents a Pareto improvement without lump sum compensation by the government. The relevance of the double dividend debate for the achievement of trade gains is discussed.

# I. Introduction

One of the most important policy issues of our time is undoubtedly the relationship between international trade and the environment. There are many aspects to this relationship. Some of them are by now well understood. For example, if a country does not implement any kind of environmental policy (to control the emissions of polluting industries) there may well be no gains from the opening up of a country to international trade. On the other hand, if it is assumed that the government implements Pigouvian taxes in the autarkic as well as free trade equilibria (and there are no other distortions in the economy) it is straightforward to prove that aggregate trade gains are ensured. This holds unconditionally if the revenue from the environmental taxation is returned lump sum to households.

The present paper is concerned with some aspects of the relationship between environmental policy and international trade which apparently are not so well understood.

One of them is the implementation of a simple and practical environmental policy rule during the move of the economy from the autarkic to the free trade equilibrium. This environmental policy rule should ensure aggregate trade gains. As is well known trade gains comprise efficiency and distributional aspects. Specifically, our aim is to put forward a practical environmental policy rule which guarantees a Pareto improvement with minimal governmental intervention.

To achieve this aim the modelling framework has to satisfy a number of key requirements.

First and foremost we have to model a multihousehold economy. If there is only one kind of household which owns all the firms it is quite unclear why the relevant externalities should not be internalised. On this important issue, see Kemp and Long (1993). In a multihousehold economy generally some households gain and others lose from free international trade, unless the government carries out redistributive policies.

Secondly, it appears that one of the frequent assumptions of second best welfare analysis, namely that governmental taxation revenue is distributed lump sum fashion to households, see e.g. Copeland (1994), often is not satisfied in the real world. All governments produce in one way or another public goods. They use taxation revenue to finance their production.

Thirdly, governments may, in certain circumstances, have more information than the private sector but it is extremely implausible that they have all the information required to implement Pigouvian taxes. Accordingly a central aim of this paper is to put forward a simple yet general rule for environmental policy which ensures trade gains (in a sense to be defined) yet has minimal informational requirements.

Fourthly, it should be emphasized right at the outset that we are con-

cerned with multilateral nondepletable (negative) externalities between firms and households, on this concept see e.g. Mas-Colell et alii (1995). It seems that most of the commonly observed forms of air or water pollution belong to this category.

The structure of the paper is as follows. In the following part II the assumptions, notation and analytical tools of environmental policy in a perfectly competitive multihousehold economy are introduced and explained.

In parts III and IV some very general results regarding welfare comparisons in distorted multihousehold economies in the tradition of e.g. Ohyama (1972), Dixit (1986) or Wong (1991) are derived and interpreted.

Two kinds of distortions are considered: the outputs of dirty goods which cause a negative externality and pure public goods which may be under or overproduced. The outputs of the dirty goods are taxed in the autarkic and free trade equilibrium. However the taxation is not necessarily optimal. To focus on essentials, we assume that there exists a fixed and monotonic relationship between emissions of pollutants and outputs. Since the analysis is global (discrete) it emerges that there are two distinct aggregate measures of the over or underproduction of public goods and over or undertaxation of the outputs of the dirty goods. Globally valid necessary and sufficient conditions for aggregate trade gains in the light of environmental and public goods policy in the two equilibria are derived and interpreted. New insights follow (inter alia) from the possibility of reversals in over or underproduction of public goods and over or undertaxation of the outputs of the dirty goods as between the two equilibria. The main results of parts III and IV are stated as Propositions I, II and the Corollary.

As mentioned before an important purpose of the paper is to put forward a simple rule for environmental policy to ensure gains from trade. This is undertaken in part V. The government changes the output taxes on the dirty goods so that the outputs of all dirty goods remain unchanged. It keeps the outputs of the public goods unchanged. Given this policy rule it can be shown that the value of output of all private goods increases at international prices. This holds even though the dirty goods are subject to output taxes in the free trade equilibrium. Implementation of this policy rule has another surprising implication. It emerges that the move to free trade represents a Pareto improvement without lump sum compensation by the government.

The proposed policy rule generalises a result derived in the context of commercial policy by Copeland in Copeland (1994) in several directions. The main result in Copeland (1994) in turn extended the work on incremental policy reform by, among others, Corden and Falvey, see Corden and Falvey (1985) and Falvey (1988). The simple environmental policy rule is referred to as a neutralisation rule because it guarantees that the price changes due to international trade do not exacerbate the distortion associated with the production of dirty (polluting) goods. To implement this rule the government

only requires information regarding the supply side of the economy.

Another contribution of the present paper is to extend in parts III and IV the time honoured analysis of welfare comparisons in multihousehold economies, see e.g.: Ohyama (1972), Dixit (1986), and Diewert (1987) or the most recent contribution in Wong (1991) to environmental problems. This extension is conditional upon making a relatively weak assumption: in the aggregate the marginal compensation requirement of households is an increasing function of the outputs of the dirty goods. Subject to this and other standard assumptions another important result follows: the law of comparative advantage in goods trade is generalised to an economy with environmental problems (consumption/production externalities), see part V.

The technique of analysis employed throughout the paper is to make global or discrete comparisons. This seems to us the most appropriate technique since the move to free trade generally entails more than local price changes. Also it is now generally accepted in the received literature, see e.g. Wong (1991). It includes the local analysis as a special case.

The paper puts forward a novel technique of welfare analysis in multihousehold economies in which agents are guided by price and quantity signals. We make use of appropriately defined aggregate compensating and equivalent variations to derive a sufficient and a necessary condition for welfare gains respectively. Assuming that the sufficient condition is satisfied we can use the necessary condition to decompose the gains from trade and to impute them to changes in price and quantity signals. This leads to several new insights, e.g. the generalization of the law of comparative advantage. We believe that this technique should prove useful in many other applications to distorted multihousehold economies.

Last but not least we point out the relevance of the double dividend debate to the achievement of trade gains (in part VII). Changes in the prices of private goods change the economic transformation set of the polluting goods and the pure public goods. A key aim of governmental policy in economies with polluting goods is to transform the latter into pure public goods. The move to free trade may increase or decrease the scope of the government to achieve this purpose. This is an important new aspect in the gains from trade analysis.

## II. Environmental Taxes in Multihousehold Economies

As explained in the introduction the analysis of gains from trade and environmental policy in parts III and IV does not make use of Pigouvian taxes because we believe that the informational requirements for implementing them are too demanding. Nonetheless, Pigouvian taxes in multihousehold



economies are derived in this part. There are two main reasons for this. Firstly, they represent an important reference point and secondly they enable us to introduce our notation, the (duality) techniques and some key assumptions which are used throughout the paper.

For simplicity we assume for the moment a small open economy with traded goods only and where the only distortions are production/consumption externalities in the sense of multilateral nondepletable negative externalities between firms and households. All standard assumptions of convex perfectly competitive economies hold.

There are  $h = 1, \dots, H$  households. Their consumption decisions are modelled by the following expenditure (minimum cost functions)<sup>1</sup>.

$$E^h(p, q, y, u^h) \quad \forall h \quad (1)$$

where:

$p$ : the vector of the prices of goods  $x$ . The production of the goods  $x$  is not polluting,

$q$ : the vector of the prices of goods  $y$ . Their production causes a negative externality,

$y$  the output vector of the polluting industries,

$u^h$  the utility level of household  $h$ .

The expenditure/minimum cost functions have all the standard properties. However they feature externalities which are treated parametrically by all households. In this context it is important to interpret the following minimum cost functions:

$$E_y^h(p, q, y, u^h) \quad \forall h \quad (2)$$

$E_y^h$  is a vector of the marginal compensation which household  $h$  requires to maintain the given utility level for small increases in  $y$ . It is analogous to the well known concept of the marginal willingness to pay for public goods.

The production side of the economy is described by the following constrained revenue or national product function<sup>2</sup>:

$$\tilde{R}(p, q, \tilde{q}, y, \bar{v}) = R(p, \tilde{q}, \bar{v}) + (q - \tilde{q})y \quad (3)$$

where:  $R_{\tilde{q}}(p, \tilde{q}, \bar{v}) = y$

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<sup>1</sup>The expenditure function is derived from a utility function,  $U^h(x^{hd}, y^{hd}, y)$ , where  $x^{hd}$ ,  $y^{hd}$  stand for the vectors of clean and dirty goods consumed by household  $h$  and  $\frac{\partial U^h}{\partial y} < 0$ . In some articles pollution is modelled as a joint output of production activities. In this case the utility function  $U^h(\cdot)$  may be regarded as a reduced form function. Our approach to the modelling of pollution is standard in the so called double dividend debate [see e.g. Bovenberg and de Mooij (1994)]. As mentioned before an assumption of our approach is that there is a fixed and monotonic relationship between the emissions of pollutants and the outputs.

<sup>2</sup>On constrained revenue or national product functions, see e.g. Abe (1992).

$\tilde{q}$  denotes the vector of virtual producer prices of the goods  $y$ ,  
 $\bar{v}$  the vector primary factor endowments.

In common with standard trade theory we assume that all factors are in fixed supply and that factor markets are perfectly competitive and distortion free. It would be easy to relax the former assumption but quite difficult to relax the latter.

As mentioned above, expression (3) may be regarded as a constrained revenue function. Later we shall make intensive use of the fact that the value of this constrained revenue function is equal to aggregate household income. The first term on the right hand side of (3) is equal to the income of firms at the prices  $p$  and  $\tilde{q}$  and the second to the (implicit) taxation revenue of the government. The function  $R(p, \tilde{q}, \bar{v})$  is a standard revenue function with all the well known properties [see e.g. Woodland (1982)]. The price vectors  $p$  and  $q$  denote world market prices.

The aggregate expenditure/income equality from (1) and (3) is:

$$\sum_h E^h(p, q, y, u^h) = R(p, \tilde{q}, \bar{v}) + (q - \tilde{q})y \quad (4)$$

Each household is endowed with  $\bar{v}^h$  of primary factors. Therefore:

$$E^h(p, q, y, u^h) = \bar{v}^h R_{\bar{v}} + I^h \quad (5)$$

where:  $R_{\bar{v}}$  is the vector of primary factor prices and  $I^h$  the amount of taxation revenue transferred to household  $h$ ;  $\sum_h I^h = (q - \tilde{q})y^3$ .

A key assumption of the present approach is that, for given  $y$ ,  $p$  and  $\bar{v}$ , virtual supply prices for the goods  $y$  exist; i.e.: that

$$R_{\tilde{q}}(p, \tilde{q}, \bar{v}) = y \quad (6)$$

can be solved for  $\tilde{q}$ .

To derive Pigouvian taxes we make use of the following trade expenditure function for multihousehold economies [see Lloyd and Schweinberger (1988)]:

$$B = \sum_h E^h(p, q, y, u^h) - R(p, \tilde{q}, \bar{v}) - (q - \tilde{q})y \quad (7)$$

Pigouvian taxes are implied only if the industries which produce the dirty goods  $y$  are optimally rationed in the sense that  $B$ , the compensated aggregate excess expenditure is minimised with respect to  $y$ :

$$B_y = \sum_h E_y^h(\cdot) - (q - \tilde{q}) = 0 \quad (8)$$

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<sup>3</sup>Note that in parts III and IV taxation revenue is used for the production of public goods.

It may be noted that expression (8) can also be obtained by differentiating totally expression (6) and substituting in for  $dy$  in terms of  $d\tilde{q}$ . This yields:

$$dB = \left[ \sum_h E_y^h - (q - \tilde{q}) \right] R_{\tilde{q}\tilde{q}} d\tilde{q} = 0 \quad (9)$$

If the matrix  $R_{\tilde{q}\tilde{q}}$  is of full rank expression (9) implies expression (8). In essence, subject to the stated assumptions, there is an analytical equivalence between output rationing and output taxation of the industries  $y$ . However, it should be carefully noted that output taxation in contrast to rationing yields revenue and therefore enables the government to produce public goods. The latter is a key concern of this paper. Therefore for policy purposes taxation and rationing are not equivalent.

Expression (8) is, of course, not sufficient to solve for  $\tilde{q}$ ,  $y$  and  $u^h$  (all  $h$ ). To solve for these variables, one needs equations (5), (6), and (8). Moreover it is essential to postulate that the trade expenditure function for multi-household economies is convex in  $y$  at least locally. To ensure this we assume that the aggregate marginal compensation requirement increases with  $y$ . We shall refer to this assumption as Assumption A. Assumption A is one of the key assumptions of the paper. It is based upon the concept of increasing marginal costs of pollution; something which seems to be widely accepted.

Now turn to the interpretation of the Pigouvian taxes:  $q - \tilde{q}$ , determined from expressions (5), (6) and (8). First note the striking similarity with the standard result for the optimal (Pareto efficient) provision of public goods. In the case of public goods the aggregate marginal willingness to pay has to be equal to the marginal cost of producing public goods. In the case of Pigouvian taxes the aggregate marginal compensation requirement has to be equal to the stringency of the output rationing of the goods  $y$  as reflected in the differences between the world market prices  $q$  and the virtual supply prices  $\tilde{q}$ . The latter is equal to the marginal cost of output changes measured at world market prices.

Note also that if the marginal compensation requirement of each household with regard to the output of each dirty good is positive and bounded away from zero, the Pigouvian taxes tend to infinity as the number of households tends to infinity. This is tantamount to a zero optimal production of dirty goods (in the limit) in very populous economies.

The taxes as determined from (5), (6) and (8) are not necessarily socially optimal Pigouvian taxes. They should be referred to as PARETIAN Pigouvian taxes (see Mirlees (1976)). The problem is that the Pigouvian taxes are not invariant with respect to changes in the distribution of income. There can be little doubt that households which have a higher living standard ( $u^h$ ) are on average more environment conscious than poorer households. For the moment we focus on efficiency and therefore the indeterminacy with regard to changes in the distribution of income brought about, for example, by lump

sum transfers, has to be accepted. Of course, similar limitations apply to the Samuelson rule for the optimal provision of public goods.

To conclude we stress again that we do not believe that governments have enough information to implement Pigouvian taxes [on this see also Copeland (1994)]. This applies especially to the demand side of the economy. However, it seems reasonable to assume that governments know (within a certain neighbourhood) the constrained revenue function. We refer to this as Assumption B. It will be recalled that constrained revenue functions have been estimated under many different assumptions for many countries, see Kohli (1991).

### III. Environmental Policy And Trade Gains: A Necessary Condition For Welfare Gains<sup>4</sup>

Throughout the paper the tools of governmental policy are the output taxes on the dirty goods  $y$  and an output vector of public goods  $G$ . The latter are produced by the government from the taxation revenues. Generally speaking the aim of the government is to transform the dirty goods  $y$  into the public goods  $G$  (for a detailed analysis of the problem in the light of the double dividend debate see part VII). Our immediate purpose is the derivation of a necessary condition under which there are potential welfare gains from trade.<sup>5</sup>

To achieve this purpose a survey of the delicate issue of welfare comparisons in multihousehold economies would now be in order. Fortunately there exists already an excellent survey of the various methods of welfare comparisons in multihousehold economies, see Wong (1991).

All the results in parts III and IV are based upon the assumption of the feasibility of lump sum transfers from the government to the various households. This assumption is relaxed in parts V, VI and VII.

At this point it seems appropriate to explain why we first derive a necessary and then a sufficient condition for potential trade gains. In standard distortion free economies it is easy to show that both the necessary condition for trade gains, stated as Proposition I and the sufficient condition, stated as Proposition II must hold. This is different in distorted economies. A key purpose of welfare analysis in distorted economies with price and quantity signals should be to decompose the possible gains from trade into gains due to the changes in the price and changes in the quantity signals. As we shall

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<sup>4</sup>Note that the analysis also applies if only some but not all goods become tradable internationally and even more generally if in the initial situation some goods are already traded.

<sup>5</sup>The criterion of potential welfare gains in a multihousehold economy was introduced in Krueger and Sonnenschein (1967).

see this procedure is essential if e.g. we want to generalise the theorem of comparative advantage to distorted economies.

The derivation of sufficient as well as necessary conditions is important for another reason as well. It is well known that one of the key problems with discrete welfare comparisons is the possibility of cycling. The possibility of cycling can be ruled out if both the necessary and the sufficient conditions hold.

We now turn to the formulation of the governmental and private sector budget constraints. The private sector budget constraint is:<sup>6</sup>

$$\sum_h E^h(p, q, y, G, u) = R(p, \tilde{q}, G, \bar{v}) + \lambda_G^s G - T \quad \text{where} \quad R_{\tilde{q}} = y$$

and  $\lambda_G^s$  stands for the vector of supply (support) prices of the public goods, and  $T$  for lump sum taxes.  $E^h(\cdot)$  denotes the relevant expenditure or minimum cost function of household  $h$ , allowing both for the effects of the outputs of the dirty goods  $y$  and the production of public goods. Expenditure functions of this form are used for example in Abe (1992), and Schweinberger (1995);  $R(\cdot)$  represents an aggregate revenue function which allows for parametrically treated outputs of the public goods. To the best of our knowledge this form of a revenue function has first been used in the analysis of public goods in Abe (1992).

In formulating the budget constraint of the private sector it has been assumed that because of nonexcludability the government cannot charge households for the provision of public goods. However, the analysis to be presented below applies with appropriate reinterpretation if the production of some or all public goods is financed not only by the government but also from private contributions.

The budget constraint of the government is as follows:

$$\lambda_G^s G = (q - \tilde{q})y + T$$

As can be seen the production of public goods is assumed to be financed from the output tax revenue as well as from lump sum taxes. This assumption is relaxed in part VI.

Substituting the governmental budget constraint into the private sector budget constraint we obtain:

$$\sum_h E^h(\cdot) = \tilde{R}(p, y, G, \bar{v}) = R(p, \tilde{q}, G, \bar{v}) + (q - \tilde{q})y \quad \text{where again} \quad R_{\tilde{q}} = y$$

From assumption A (see the preceding part II):

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<sup>6</sup>In the following expression  $\lambda_G^s$  is defined as a vector whose elements are positive i.e.:  $\lambda_g^s = -R_G$ , see Abe (1992).

$$E^h(p^0, q^0, y^1, G^1, u^{h0}) \geq E^h(p^0, q^0, y^0, G^0, u^{h0}) + E_{y^0}^h(y^1 - y^0) + E_{G^0}^h(G^1 - G^0) \quad (10)$$

where the superscripts denote two equilibria with different prices, outputs, output taxes on the goods  $y$ , as well as vectors  $G$ .

Expression (10) follows from the fact that a Taylor's expansion globally understates the true value of a convex function.

Summing (10) over all households we have:

$$\sum_h E^h(p^0, q^0, y^1, G^1, u^{h0}) \geq \sum_h E^h(p^0, q^0, y^0, G^0, u^{h0}) + \sum_h E_{y^0}^h(y^1 - y^0) + \sum_h E_{G^0}^h(G^1 - G^0) \quad (11)$$

From the above formulation of the private sector budget constraint the aggregate expenditure/income equality in the initial autarkic equilibrium is:

$$\sum_h E^h(p^0, q^0, y^0, G^0, u^{h0}) = \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) \quad (12)$$

Expression (11) can be rewritten [in the light of expression (12)] as follows:

$$\sum_h E^h(p^0, q^0, y^1, G^1, u^{h0}) \geq \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) + \sum_h E_{y^0}^h(y^1 - y^0) + \sum_h E_{G^0}^h(G^1 - G^0) \quad (13)$$

We now deduct from both sides:  $\sum_h E^h(p^0, q^0, y^1, G^1, u^{h1})$ . This yields:

$$\begin{aligned} \sum_h E^h(p^0, q^0, y^1, G^1, u^{h0}) - \sum_h E^h(p^0, q^0, y^1, G^1, u^{h1}) &\geq \\ \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - \sum_h E^h(p^0, q^0, y^1, G^1, u^{h1}) &+ \\ \sum_h E_{y^0}^h(y^1 - y^0) + \sum_h E_{G^0}^h(G^1 - G^0) &\end{aligned} \quad (14)$$

From now on we refer to the left hand side of expression (14) as L.H.S. From the concavity of the expenditure functions in the prices  $p$  and  $q$ :

$$\sum_h E^h(p^0, q^0, y^1, G^1, u^{h1}) \leq \sum_h E^h(p^1, q^1, y^1, G^1, u^{h1}) + (p^0 - p^1)x^{D1} + (q^0 - q^1)y^{D1} \quad (15)$$

where  $x^{D1}$  and  $y^{D1}$  stand for the vectors of goods demanded in the free trade equilibrium.

In the new equilibrium:

$$\sum_h E^h(p^1, q^1, y^1, G^1, u^{h1}) = \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) \quad (16)$$

Substituting (16) into (15) and making use of (15) to rewrite (14) we arrive at:

$$L.H.S. \geq \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) - (p^0 - p^1)x^{D1} - (q^0 - q^1)y^{D1} + \sum_h E_{y^0}^h(y^1 - y^0) + \sum_h E_{G^0}^h(G^1 - G^0) \quad (17)$$

Now write

$$\tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) = \left( \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - \tilde{R}(p^0, q^0, y^1, G^1, \bar{v}) \right) + \left( \tilde{R}(p^0, q^0, y^1, G^1, \bar{v}) - \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) \right)$$

From the convexity of  $\tilde{R}(\cdot)$  in  $p$  and  $q$ :

$$\tilde{R}(p^0, q^0, y^1, G^1, \bar{v}) \geq \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) + (p^0 - p^1)x^1 + (q^0 - q^1)y^1 \quad (18)$$

Since  $\tilde{R}(\cdot)$  is concave in  $y$  and  $G$ , we have:

$$\tilde{R}(p^0, q^0, y^1, G^1, \bar{v}) \leq \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) + (q^0 - \tilde{q}^0)(y^1 - y^0) + \lambda_{G^0}^s(G^1 - G^0) \quad (19)$$

Expression (19) follows, because from the relevant analogue of expression (3) of part II,  $\tilde{R}_y = (q - \tilde{q})$ .

Multiplying expression (19) by minus one and adding the last two expressions we have:

$$\tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) \geq (p^0 - p^1)x^1 + (q^0 - q^1)y^1 - (q^0 - \tilde{q}^0)(y^1 - y^0) - \lambda_{G^0}^s(G^1 - G^0) \quad (20)$$

Formally rewriting expression (17) in the light of (20) we arrive at the following final result:

$$L.H.S. \geq -(p^0 - p^1)m_x^1 - (q^0 - q^1)m_y^1 - (q^0 - \tilde{q}^0)(y^1 - y^0) - \lambda_{G^0}^s(G^1 - G^0) + \sum_h E_{y^0}^h(y^1 - y^0) + \sum_h E_{G^0}^h(G^1 - G^0) \quad (21)$$

where:  $m_x^1, m_y^1$  denote the import vectors of the goods  $x$  and  $y$  in the free trade equilibrium.

Since our purpose is to derive a necessary condition for Pareto improving changes in the prices and the outputs of the goods  $y$  and  $G$ , we now assume that the L.H.S. is negative and therefore the right hand side of expression (21) has to be negative too<sup>7</sup>, i.e.:

$$(p^0 - p^1)m_x^1 + (q^0 - q^1)m_y^1 + \left[ (q^0 - \tilde{q}^0) - \sum_h E_{y^0}^h \right] (y^1 - y^0) + \left[ -\lambda_{G^0}^s - \sum_h E_{G^0}^h \right] (G^1 - G^0) > 0 \quad (22)$$

Expression (22) highlights three distinct effects of international trade and environmental policy:

(1) a price effect as reflected in  $(p^0 - p^1)m_x^1 + (q^0 - q^1)m_y^1$ . If this expression is positive the law of comparative advantage in goods trade holds.

(2) an environmental policy effect:  $[(q^0 - \tilde{q}^0) - \sum_h E_{y^0}^h](y^1 - y^0)$ , and

(3) a public goods policy effect:  $[-\lambda_{G^0}^s - \sum_h E_{G^0}^h](G^1 - G^0)$ .

The effects listed under 2 and 3 above can be labeled as effects associated with quantity signals.

The environmental policy and the public goods effects are multihousehold analogues of the  $g$  or externality effects in e.g. Abe (1992).

The coefficients of the vectors  $y^1 - y^0$  and  $G^1 - G^0$  can be referred to as "aggregate utility prices". Sometimes they are also referred to as Paretian shadow prices but this usage may give rise to a misunderstanding, see Stern and Drèze (1986).

In deriving expression (22) we have assumed that  $\sum_h E^h(p^0, q^0, y^1, G^1, u^{h0}) - \sum_h E^h(p^0, q^0, y^1, G^1, u^{h1})$  is negative. This assumption is equivalent to assuming potential aggregate trade gains. By aggregate trade gains we mean that the gainers from free trade can compensate the losers and still gain<sup>8</sup>. This

<sup>7</sup>Note that the following condition is necessary for a Pareto improvement even if the government does not carry out any redistributive policy.

<sup>8</sup>The expression on the L.H.S. could also be interpreted as the sum of appropriately defined aggregate equivalent variation in distorted economies, see Boadway and Bruce (1993).



rather traditional interpretation may be replaced by a more modern political economy interpretation. Let political support for the move to free trade depend upon contributions to the government, see e.g. Grossman and Helpman (1994). Then a necessary condition for an increase in political support is that the gainers are willing to contribute more to achieve a move to free trade than the losers are willing to contribute to avoid the policy change.

We are now in a position to state Proposition I.

Proposition I

Assume that the move to free trade represents a Pareto improvement. Then:

$$(p^0 - p^1)m_x^1 + (q^0 - q^1)m_y^1 + [(q^0 - \tilde{q}^0) - \sum_h E_{y^0}^h](y^1 - y^0) + [-\lambda_{G^0}^s - \sum_h E_{G^0}^h](G^1 - G^0) \geq 0$$

Proof: Proposition I follows from expression (22) and its derivation, see expressions (10) to (21). Q.E.D.

## IV. Environmental Policy And Trade Gains: A Sufficient Condition For Welfare Gains

In part III we derived a necessary condition for a Pareto improvement in an economy with production/consumption externalities. We now turn to the derivation of a sufficient condition.

Assuming that the sufficient condition is satisfied we know that there are aggregate trade gains in the sense of the incomplete weak compensation test, see Wong (1991), because an appropriately defined aggregate compensating variation is non-negative. Furthermore we know that if compensation is actually carried out, the necessary condition for aggregate trade gains must also hold. This enables us to decompose aggregate trade gains into gains due to price and gains due to quantity signals.

From assumption A of part II:

$$\begin{aligned} \sum_h E^h(p^1, q^1, y^0, G^0, u^{h1}) &\geq \sum_h E^h(p^1, q^1, y^1, G^1, u^{h1}) \\ &\quad + \sum_h E_{y^1}^h(y^0 - y^1) + \sum_h E_{G^1}^h(G^0 - G^1) \end{aligned} \quad (23)$$

Setting

$$\sum_h E^h(p^1, q^1, y^1, G^1, u^{h1}) = \tilde{R}(p^1, q^1, y^1, G^1, \bar{v})$$

and deducting from both sides:

$$\sum_h E^h(p^1, q^1, y^0, G^0, u^{h0})$$

we obtain:

$$\begin{aligned} L.H.S. = \sum_h E^h(p^1, q^1, y^0, G^0, u^{h1}) - \sum_h E^h(p^1, q^1, y^0, G^0, u^{h0}) \geq \\ \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) - \sum_h E^h(p^1, q^1, y^0, G^0, u^{h0}) \\ + \sum_h E_{y^1}^h(y^0 - y^1) + \sum_h E_{G^1}^h(G^0 - G^1) \quad (24) \end{aligned}$$

From the concavity of  $E^h(\cdot)$  in  $p$  and  $q$  and setting  $\sum_h E^h(p^0, q^0, y^0, G^0, u^{h0})$  equal to  $\tilde{R}(p^0, q^0, y^0, G^0, \bar{v})$  we arrive at:

$$\sum_h E^h(p^1, q^1, y^0, G^0, u^{h0}) \leq \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) + (p^1 - p^0)x^{D0} + (q^1 - q^0)y^{D0} \quad (25)$$

Expression (24) can be rewritten in the light of expression (25) as follows:

$$\begin{aligned} L.H.S. \geq \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) - \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) - (p^1 - p^0)x^{D0} \\ - (q^1 - q^0)y^{D0} + \sum_h E_{y^1}^h(y^0 - y^1) + \sum_h E_{G^1}^h(G^0 - G^1) \quad (26) \end{aligned}$$

From the concavity of  $\tilde{R}(\cdot)$  in  $y$  and  $G$ :

$$\tilde{R}(p^1, q^1, y^0, G^0, \bar{v}) \leq \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) + (q^1 - \tilde{q}^1)(y^0 - y^1) + \lambda_{G^1}^s(G^0 - G^1) \quad (27)$$

From the convexity of  $\tilde{R}(\cdot)$  in the prices  $p$  and  $q$ :

$$\tilde{R}(p^1, q^1, y^0, G^0, \bar{v}) \geq \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) + (p^1 - p^0)x^0 + (q^1 - q^0)y^0 \quad (28)$$

From expression (27) and (28) it follows that:

$$\begin{aligned} \tilde{R}(p^1, q^1, y^1, G^1, \bar{v}) - \tilde{R}(p^0, q^0, y^0, G^0, \bar{v}) \geq (p^1 - p^0)x^0 + (q^1 - q^0)y^0 - \\ (q^1 - \tilde{q}^1)(y^0 - y^1) - \lambda_{G^1}^s(G^0 - G^1) \quad (29) \end{aligned}$$

Rewriting (26) in the light of (27) we obtain the final result (noting that  $x^0 = y^0$ ):

$$L.H.S. \geq - \left[ \sum_h E_{y^1}^h - (q^1 - \tilde{q}^1) \right] (y^1 - y^0) - \left[ \sum_h E_{G^1}^h - \lambda_{G^1}^s \right] (G^1 - G^0) \quad (30)$$

Expression (30) yields the following sufficient condition for welfare gains:<sup>9</sup>

$$\left[ (q^1 - \tilde{q}^1) - \sum_h E_{y^1}^h \right] (y^1 - y^0) + \left[ -\lambda_{G^1}^s - \sum_h E_{G^1}^h \right] (G^1 - G^0) > 0 \quad (31)$$

Note that the coefficients of  $(y^1 - y^0)$  and  $(G^1 - G^0)$  are different in expressions (21) and (31). From expression (8) of part II the coefficients of  $(y^1 - y^0)$  may be interpreted in terms of over- or undertaxation of the outputs of the dirty goods. Similarly the coefficients of  $(G^1 - G^0)$  may be regarded as measures of the over- or underproduction of public goods. In comparing expressions (21) and (31) it is obvious that the outputs of dirty goods which were undertaxed in the autarkic equilibrium may be overtaxed in the free trade equilibrium and vice versa. The same applies to the under- or overproduction of public goods. This possibility is generally ignored in a strictly local analysis. As we shall see shortly, the possibility of reversals of over- or undertaxation of the goods  $y$  and over- and underproduction of public goods plays a key role in the generalisation of the law of comparative advantage to an economy with dirty private and pure public goods.

Expression (31) and a comparison of expressions (31) and (21) give rise to the following Proposition II and the Corollary to Propositions I and II.

#### Proposition II

Assume that the move to free trade is associated with output changes in  $y$  and  $G$  such that:

$$[(q^1 - \tilde{q}^1) - \sum_h E_{y^1}^h](y^1 - y^0) + [-\lambda_{G^1}^s - \sum_h E_{G^1}^h](G^1 - G^0) > 0$$

Then the move to free trade implies a Pareto improvement if lump sum compensation is feasible and actually carried out.

*Proof:* We compare three distinct equilibria: the autarkic equilibrium, the equilibrium with free trade prices but autarkic outputs of the goods  $y$  and  $G$  and the free trade equilibrium. This procedure enables us to relate our analysis and results to the standard analysis in terms of consumption

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<sup>9</sup>The L.H.S. of expression (30) may be interpreted as an aggregate of compensating variations of households in distorted economies, see e.g. Boadway and Bruce (1993) or Wong (1991).

and production gains. It is also relevant for the results of the following part V.

From standard envelope properties of the expenditure or minimum cost functions:

$$\sum_{h=1}^H E^h(p^1, q^1, y^0, G^0, u^{h_0}) \leq p^1 x^{DO} + q^1 y^{DO}$$

This inequality implies an aggregate consumption gain of:  $p^1 x^{DO} + q^1 y^{DO} - \sum_h E^h(\cdot)$ .

From the autarkic equilibrium conditions it follows that  $x^{DO} = x^0$  and  $y^{DO} = y^0$

Also from revenue maximisation at the world market prices  $p^1$  and  $q^1$ , we obtain:

$$p^1 x^0 + q^1 y^0 \leq p^1 x^1(p^1, q^1, y^0, G^0, \bar{v}) + q^1 y^0$$

This inequality holds if the outputs of the goods  $y$  and  $G$  are kept fixed at the autarkic levels, see also the subsequent part V. The expression  $p^1 x^1(\cdot) + q^1 y^0 - p^1 x^0 - q^1 y^0$  may be interpreted as a conditional production gain (conditional upon  $y$  and  $G$  being kept fixed).  $\clubsuit$

From the expenditure income equality in the free trade equilibrium with  $G = G^0$  and  $y = y^0$ .

$$p^1 x^1(p^1, q^1, y^0, G^0, \bar{v}) + q^1 y^0 = \tilde{R}(p^1, q^1, y^0, G^0, \bar{v}) = \sum_h E^h(p^1, q^1, y^0, G^0, u^{h*})$$

where  $u^{h*}$  denotes the level of utility of household  $h$  in the said equilibrium. To complete the proof we make use of a multihousehold trade expenditure function of distorted economies, see Lloyd and Schweinberger (1988):  $B(p, q, y, G, u^1, \dots, u^H) = \sum_h E^h((p, q, y, G, u^h) - \tilde{R}(p, q, y, G, \bar{v}))$ . This function is convex in  $G$  and  $y$  from Assumption A of part II. The gradient vectors of  $B(\cdot)$  with respect to  $y$  and  $G$  are:

$$B_y = \sum_h E_y^h - (q - \bar{q}) \text{ and}$$

$$B_G = \sum_h E_G^h + \lambda_G^s$$

From the convexity of  $B(\cdot)$  in  $y$  and  $G$ :

$$B(p^1, q^1, y^0, G^0, \bar{v}; u^{11}, \dots, u^{H1}) \geq B(p^1, q^1, y^1, G^1, \bar{v}; u^{11}, \dots, u^{H1}) + \dots \\ B_{y^1}(y^0 - y^1) + B_{G^1}(G^0 - G^1)$$

From the condition of Proposition II:  $B_{y^1}(y^0 - y^1) + B_{G^1}(G^0 - G^1) \geq 0$  Since  $B(p^1, q^1, y^1, G^1, \bar{v}; u^{11}, \dots, u^{H1}) = 0$  it follows that:

$$\begin{aligned}
B(p^1, q^1, y^0, G^0, \bar{v}; u^{11}, \dots, u^{H1}) &\geq B(p^1, q^1, y^0, G^0, \bar{v}; u^{1*}, \dots, u^{H*}) \\
&\geq B(p^1, q^1, y^0, G^0, \bar{v}; u^{10}, \dots, u^{H0})
\end{aligned}$$

Q.E.D.

The difference:

$$B(p^1, q^1, y^0, G^0, \bar{v}; u^{11}, \dots, u^{H1}) - B(p^1, q^1, y^0, G^0, \bar{v}; u^{1*}, \dots, u^{H*})$$

may be interpreted as the aggregate gain or loss due to externality effects. Generally, this difference may be positive or negative. If it is negative it has to be added to the aggregate consumption and the conditional production gain to determine whether the move to free trade entails potential aggregate gains. Making use of the preceding analysis we could, of course, work out a precise necessary and sufficient condition for aggregate potential trade gains.

We now turn to the generalisation of the law of comparative advantage. In this context two features of expression (31) and Proposition II are noteworthy:

- (a) the definition of the environmental and public goods policy effects used in Proposition I is not the same as in Proposition II,
- (b) there is no price effect in Proposition II.

We now derive a corollary of proposition I and II.

Corollary to Propositions I and II

Assume that

$$\left[ (q^1 - \tilde{q}^1) - \sum_h E_{y^1}^h \right] (y^1 - y^0) + \left[ - \sum_h E_{G^1}^h - \lambda_{G^1}^s \right] (G^1 - G^0) > 0$$

but

$$\left[ (q^0 - \tilde{q}^0) - \sum_h E_{y^0}^h \right] (y^1 - y^0) + \left[ - \sum_h E_{G^0}^h - \lambda_{G^0}^s \right] (G^1 - G^0) < 0$$

Then the law of comparative advantage holds in an economy with negative multilateral nondepletive externalities and publicly produced pure public goods.

The conditions of the Corollary clearly represent a formalisation of the concept of reversals, in the aggregate of the over and undertaxation of the outputs of the dirty goods and over and underproduction of the public goods as between the two equilibria.

Proof: The Corollary follows directly from proposition II and the derivation of expression (21).

Q.E.D.

Propositions I and II and the Corollary represent very general results on welfare comparisons in distorted economies which extend and generalize the work of Ohyama (1972), Woodland (1982), Dixit (1986), and especially Wong (1991) to a multihousehold economy with pure public and some dirty (polluting) private goods.

By relating the value of an appropriately defined aggregate compensating variation to the corresponding aggregate equivalent variation, we have decomposed the aggregate trade gains into gains due to price and quantity signals respectively. This novel technique should prove useful in many other applications too.

## V. The Neutralisation Rule and the Law of Comparative Advantage

The purpose of this part is twofold. Firstly we put forward a simple yet general environmental policy rule which, if followed, ensures that there are potential trade gains. Secondly, we show that if this rule is implemented, the law of comparative advantage in goods trade holds. To the best of our knowledge the law of comparative advantage to date has not been extended to economies with environmental problems. Maybe this is due to the fact that the decomposition of trade gains into gains due to changes in price and quantity signals as reflected in Proposition I has not been undertaken before. The neutralisation rule is an extension and generalisation of an important result in Copeland (1994) to multihousehold economies with produced pure public goods.

We first state the NEUTRALISATION RULE. To this end we make use of the constrained revenue function  $R = R(p, \tilde{q}, G, \bar{v})$ .

### THE NEUTRALISATION RULE

The government is said to implement the Neutralisation Rule if:

$$R_{\tilde{q}}(p^0, \tilde{q}^0, G^0, \bar{v}) = y^0 = y^1 = R_{\tilde{q}}(p^1, \tilde{q}^1, G^1, \bar{v}) \text{ and } G^0 = G^1. \quad (32)$$

The Neutralisation Rule is feasible because the outputs of all public goods are policy instruments and if there are  $n$  outputs of dirty goods as targets there are also  $n$  available instruments, namely  $n$  output taxes.

An immediate implication of the Neutralisation Rule is the following LEMMA:

### LEMMA

Let the Neutralisation Rule of environmental policy be followed. Then from expressions (21) and (22) and the preceding analysis:

$$\begin{aligned} & \sum_h E^h(p^0, q^0, y^0, G^0, u^{h0}) - \sum_h E^h(p^0, q^0, y^0, G^0, u^{h1}) \geq \\ & (p^0 - p^1)m_x^1 + (q^0 - q^1)m_y^1 + \left[ (q^0 - \tilde{q}^0) - \sum_h E_{y^0}^h \right] (y^1 - y^0) \\ & + \left[ -\lambda_G^s - \sum_h E_{G^0}^h \right] (G^1 - G^0) = (p^0 - p^1)m_x^1 + (q^0 - q^1)m_y^1 \end{aligned}$$

Furthermore from expression (31):

$$\begin{aligned} & \sum_h E^h(p^1, q^1, y^1, G^1, u^{h1}) - \sum_h E^h(p^1, q^1, y^1, G^1, u^{h0}) \geq \\ & \left[ (q^1 - \tilde{q}^1) - \sum_h E_{y^1}^h \right] (y^1 - y^0) + \left[ -\lambda_{G^1}^s - \sum_h E_{G^1}^h \right] (G^1 - G^0) = 0 \end{aligned}$$

The preceding LEMMA is important because it shows that the L.H.S. of the inequality is the standard expression for the aggregate equivalent and compensating variations respectively. As Wong has shown in Wong (1991) a necessary and sufficient condition for the weak incomplete compensation test (WICT) is that the aggregate compensating variation is nonnegative, see his Proposition I on page 55.

The following Proposition III relates the law of comparative advantage in an economy with environmental problems and pure public goods to the Neutralisation rule and the preceding LEMMA.

### Proposition III

Assume that the NEUTRALISATION RULE of environmental policy, for a definition see expression (32), is followed as the economy moves from the autarkic to the free trade equilibrium. Then the law of comparative advantage in goods trade holds.

An interesting question arises in this context. What is the source of gains from trade if the neutralisation rule of environmental policy is followed?

It is straightforward to show that the source of trade gains are standard production gains accruing from the changes in the production of the clean goods  $x$ . The value of output of the private goods at world market prices is  $p^1x + q^1y$ . The latter is maximised (given perfect competition and distortion free factor markets) subject to the transformation set  $g(x, y, G, \bar{v}) \leq 0$ . Since  $q^1, y$  and  $G$  are fixed it follows at once that  $p^1(x^1 - x^0) \geq 0$  (see also the

proof of Proposition II).

It should be noted that this result holds even though the prices faced by producers of the dirty goods,  $\tilde{q}$ , change as the economy moves from the autarkic to the free trade equilibrium and the prices  $\tilde{q}^1$  are, of course, generally different from the world market prices  $q^1$ . This result is an extension and generalisation of results derived initially by Corden and Falvey, in Corden and Falvey (1985) and most recently by Copeland in Copeland (1994). Corden and Falvey showed that there is an interesting asymmetry between tariffs and quotas. In a small open economy without other distortions a trading equilibrium with only quotas is a constrained Pareto efficient equilibrium. This is not the case with tariffs. Copeland (1994) extended this result to economies with multilateral nondepletable negative externalities by proving that a reduction in a tariff on a traded good improves welfare in a one household economy if there are quotas on the pollutants.

We now turn to the (in our viewpoint) most important issue of changes in the distribution of income and environmental policy in multihousehold economies. It is well known that generally trade and environmental policies are conflict generating between households because they result in price changes. This is an issue which will be taken up in some detail in the final part VII. At the moment we shall show that for plausible patterns of factor ownership of households implementation of the Neutralisation Rule rather surprisingly entails a Pareto improvement without any other kind of governmental intervention.

## VI. The Neutralisation Rule and Pareto Improvement without Lump Sum Compensation

In this part we want to prove that, given the neutralisation rule, compensation by means of lump sum transfers is unnecessary to achieve a Pareto improvement, consumption or employment taxes or subsidies are sufficient. This result extends similar results obtained by Dixit and Norman in Dixit and Norman (1980) and (1985) to economies with environmental externalities and public goods. The same holds for the analysis contained in Wong (1991). We follow the approach in Dixit and Norman (1980) and (1985).<sup>10</sup> The proof proceeds by considering three different equilibria: The autarkic equilibrium, a compensated equilibrium and the uncompensated free trade equilibrium. In the compensated equilibrium firms produce at world market prices the goods  $x$  and the goods  $y$  and  $G$  whose outputs are kept fixed as the economy moves from the autarkic to the free trade equilibrium (by means of appro-

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<sup>10</sup>As is clear from the exchange between Dixit and Norman (1985) and Kemp and Wan (1985), a key assumption in the following analysis is that the Weymark condition is satisfied, see also Weymark (1978).



priate adjustment of the output taxes). In the compensated equilibrium the government employs commodity and factor employment taxes/subsidies so that each household faces the same prices as in the autarkic equilibrium. We now prove that the government achieves a budget surplus in the compensated equilibrium. The budget surplus in the compensated equilibrium is:

$$B = (p^{D0} - p^1) \sum_h x^{hD0} + (q^{D0} - q^1) \sum_h y^{hD0} + (w^1 - w^0) \sum_h \bar{v}^h \quad (33)$$

where:  $x^{hD0}$  and  $y^{hD0}$  denote the consumption vector of household  $h$  of goods  $x$  and  $y$  respectively in autarkic equilibrium and  $p^{D0}$  and  $q^{D0}$  the respective prices faced by households, the  $w$ 's stand for factor prices.

Since in autarkic equilibrium:

$$p^{D0} \sum_h x^{hD0} + q^{D0} \sum_h y^{hD0} = w^0 \sum_h \bar{v}^h$$

and in the compensated equilibrium:

$$w^1 \sum_h \bar{v}^h = p^1 x^1 + q^1 y^1 \quad \text{and} \quad y^1 = \sum_h y^{hD0} = y^0$$

it follows that:

$$B = p^1(x^1 - x^0) > 0 \quad (34)$$

The budget surplus is, as expected, exactly equal to the production gain which has been shown to be positive.

Keeping<sup>1</sup> in the compensated equilibrium all the employment taxes or subsidies unchanged the government may increase the utility of all households by reducing consumption prices through a reduction in commodity taxes or increases in subsidies. Subject to the simple NEUTRALISATION rule stated as expression (32), the government may therefore bring about a Pareto improvement (without lump sum transfers).

## VII. The Double Dividend Debate and the Gains from Trade

As mentioned in the introduction, an important aim of governmental policy in economies with dirty private goods is to transform them into clean public goods. To this end the outputs of the dirty goods are taxed and the taxation revenue is used to produce clean public goods. The ability of the government to achieve this transformation is at the heart of the so called double dividend debate, for a survey see e.g. Goulder (1994). The double dividend debate is of

extreme relevance to the topic of the present paper: the achievement of trade gains under various environmental and public goods policies. The converse applies too. As we shall show,<sup>11</sup> the literature on the gains from trade in distorted economies is directly relevant to the issues discussed in the double dividend debate. The reason for this is obvious: the changes in the prices of the private goods associated with the move to free trade have a direct and possibly very significant effect on the ability of the government to transform the dirty private goods into the clean public goods. The distributional issues raised in the previous part VI also impinge on the double dividend debate. Lowering the outputs of the dirty goods and producing more clean public goods clearly has a double dividend effect on each household on the demand side. As is well known from the literature on public goods an increase in the outputs of public goods is equivalent to an increase in household income. Reducing the outputs of the dirty goods implies a further increase in this income. Furthermore the greater the number of households in the economy the greater the "implicit" income increases for given decreases in the outputs of the dirty goods and increases in the outputs of the clean public goods.

However the supply side has to be considered too. Actual household income may decline because of changes in the supply prices of the dirty goods. There is therefore no guarantee that the double dividend effect is strong enough to entail a Pareto improvement. Whether the double dividend effect is or is not strong enough depends, *inter alia*, on the prices of the private goods. It follows that the change from the autarkic to the free trade equilibrium may increase or decrease the ability of the government to bring about Pareto improvements through the transformation of dirty private goods into clean public goods (with or without lump sum compensation).

To derive precise results we first define an economic transformation set in the output space of dirty private goods and public goods. In what follows we assume that the production sector is on the boundary of the transformation set, i.e.: that  $g(x, y, G, \bar{v}) = 0$ . Since the value of output of private goods is maximised at the given supply prices it is straightforward to derive the following supply functions of the clean private goods  $x$ ;  $x = x(p, \tilde{q}, G, \bar{v})$ , where  $\tilde{q} = \tilde{q}(p, y, G, \bar{v})$  stands for the vector of supply (support) prices of the dirty goods  $y$ . Substituting the supply functions of the clean private goods into the physical transformation set  $g(x, y, G, \bar{v}) = 0$  we obtain the following economic transformation set:

$$g^E[x(p, \tilde{q}, G, \bar{v}), y, G, \bar{v}] = 0 \quad (35)$$

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<sup>11</sup>Very surprisingly, it appears that this is the first paper which addresses itself to the issue of relating the double dividend debate to gains from trade and vice versa. The double dividend debate generally ignores the distributional issues of multihousehold economies. The present paper therefore represents a contribution not only to the literature on gains from trade but also the double dividend debate.

where:  $\tilde{q} = \tilde{q}(p, y, G, \bar{v})$ .

Economic transformation sets are implicit in many areas of public economics, see e.g. the literature on optimal provision of public goods if the production of the latter is financed from distortionary taxation, see e.g. Atkinson and Stiglitz (1980). In the present context it is important to define the economic transformation set formally because we want to capture the effect of changes in  $y$  or  $\tilde{q}$  and  $G$  on the outputs of the clean private goods  $x$ . This is an effect which is beyond the direct control of the government.

Differentiating expression (35) totally with respect to  $y$  and  $G$  we have:

$$(MC_x x_{\tilde{q}} \tilde{q}_y + MC_y) dy + [MC_x(x_G + x_{\tilde{q}} \tilde{q}_G) + MC_G] dG = 0 \quad (36)$$

where:  $MC_x, MC_y$  and  $MC_G$  denote the vectors of marginal costs associated with the outputs of the goods  $x, y$  and  $G$  respectively.

Expression (36) allows us to deduce the marginal rate of economic transformation between anyone dirty private good and anyone public good. It also shows that not all the  $dy$  and  $dG$  can be chosen independently except if  $dy = dG = 0$ .

We now turn to the budget constraint of each household. Differentiating the revenue function  $R = R(p, \tilde{q}, G, \bar{v})$  with respect to  $\bar{v}$ , we obtain the competitive factor prices or rentals, see e.g. Abe (1992). The factor prices are functions of  $p, \tilde{q}, G$  and  $\bar{v}$ , i.e.:  $w = w(p, \tilde{q}, G, \bar{v})$ . To simplify the analysis we assume that, for given prices  $p$  and  $\tilde{q}$ , changes in the outputs of the public goods do not change the factor prices  $w$ ; i.e.: ceteris paribus changes in the outputs of  $G$  have only Rybczynski effects.<sup>12</sup>

The income/expenditure equality of each household is:

$$E^h(p, q, y, G, u^h) = \bar{v}^h w \quad (37)$$

where:  $w = w(p, \tilde{q}, G, \bar{v})$  and  $\tilde{q} = \tilde{q}(p, y, G, \bar{v})$

Differentiating expression (37) with respect to  $y$  and  $G$  we have:

$$E_{u^h}^h du^h = (\bar{v}^h w_{\tilde{q}} \tilde{q}_y - E_y^h) dy + (\bar{v}^h w_{\tilde{q}} \tilde{q}_G - E_G^h) dG \quad (38)$$

To obtain our final result we assume that there is only one public good and one private good  $y$ . Solving expression (36) for  $dy$  in terms of  $dG$  and substituting into expression (38) we arrive at:

$$E_{u^h}^h \frac{du^h}{dG} = (\bar{v}^h w_{\tilde{q}} \tilde{q}_y - E_y^h) \frac{dy}{dG} + (\bar{v}^h w_{\tilde{q}} \tilde{q}_G - E_G^h) \quad (39)$$

where:

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<sup>12</sup>We assume that the number of produced private goods is equal to the number of factors and the Jacobian determinant of the cost functions is nonvanishing for all prices  $p$  and  $\tilde{q}$ .

$$\frac{dy}{dG} = -\frac{MC_x(x_G + x_{\tilde{q}}\tilde{q}_G) + MC_G}{MC_x x_{\tilde{q}}\tilde{q}_y + MC_y}$$

Expression (39) highlights why a positive double dividend effect, i.e.:  $-E_y^h \frac{dy}{dG} - E_G^h$  may not imply a welfare improvement of household  $h$ . Firstly, there is no guarantee that the marginal rate of economic transformation, the sign of  $\frac{dy}{dG}$  is negative. If the marginal rate of economic transformation is positive it may be that the double dividend effect is negative rather than positive. Secondly, even if the marginal rate of economic transformation  $\frac{dy}{dG}$  is negative and therefore the double dividend effect positive, the Stolper-Samuelson effect,  $\bar{v}^h w_{\tilde{q}}(\tilde{q}_y \frac{dy}{dG} + \tilde{q}_G)$ , may well be negative and large enough to more than offset the positive double dividend effect. Making use of the techniques developed in Lloyd and Schweinberger (1988), it is easy to show that  $\bar{v}^h w_{\tilde{q}}$  represents the output of the dirty good  $y$  imputed to household  $h$ . This imputed output may be positive or negative. A negative imputed output of good  $y$  implies and is implied by a household factor endowment vector which lies outside the diversification cone of the economy.

The main result implicit in this analysis is now formalised as Proposition IV.

#### Proposition IV

The transformation of the private good  $y$  into the public good  $G$  implies a Pareto improvement (without lump sum compensation) if:

$$\bar{v}^h w_{\tilde{q}}(\tilde{q}_y \frac{dy}{dG} + \tilde{q}_G) > E_y^h \frac{dy}{dG} + E_G^h \quad \forall h \quad (40)$$

Proof: Proposition IV follows directly from expression (39) and the preceding analysis. Q.E.D.

Proposition IV contains two important messages. Firstly in defining the relevant double dividend effect the marginal rate of economic transformation of the dirty private good into the public good must not be ignored. Secondly the relevant Stolper-Samuelson effect also depends on this marginal rate of economic transformation. From this follows that even households whose imputed output of good  $y$  is negative (i.e.: have a comparative advantage in the production of the clean private goods) do not necessarily gain from the transformation of the good  $y$  into the good  $G$ .

Proposition IV may be regarded as an analogue of the Weymark condition, see Weymark (1979), with regard to the transformation of the dirty private good  $y$  into the clean public good  $G$ .

Most importantly, generally speaking, for our purpose the transformation of the good  $y$  into the good  $G$  may for some households add to the gains from international trade due to changes in the prices of the goods  $x$  and  $y$ , but

for others reduce the gains or even turn them into net losses. The condition stated in Proposition IV may be satisfied at free trade prices but violated at autarkic prices or vice versa. The analysis of trade gains therefore assumes in this policy setting an entirely new dimension.

## References

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## **Workshop 1995**

### **Environmental Policy in Open Economies**

June 5-7, 1995  
Waldhaus Jakob, Eichhornstrasse 84, D-78464 Konstanz

#### **Monday, June 5, 1995**

19.00 - 21.00     Welcome Reception.

#### **Tuesday, June 6, 1995**

*Chairman:* Heinrich Ursprung.

9.00 - 9.45     *Opening Address:* Hans-Jürgen Vosgerau (Speaker of the SFB 178, Konstanz).

*Introduction:*     Bernd Genser (SFB 178, Konstanz).

9.45 - 10.30     Coffee Break.

10.30 - 12.00     James R. Markusen (University of Colorado, Boulder):  
*Costly Pollution Abatement, Competitiveness, and Plant Location Decisions.*  
*Discussant:*     Ulrich Landwehr (University of Mannheim).

Gunter Stephan (University of Bern):  
*Laissez-Faire, International Cooperation or National Greenhouse Policy:*  
*A CGE Study.*

*Discussant:*     Andreas Haufler (University of Konstanz).

12.00 - 14.00     Lunch Break.

14.00 - 15.30     Roger D. Congleton (George Mason University):  
*Return to Rio: On the Political Economy of Environmental Treaties.*  
*Discussant:*     Hans Peter Grüner (University of Konstanz).

Rolf Bommer (SFB 178, Konstanz):  
*Endogenous Environmental Policy and Trade Liberalization - A Signaling Approach.*

*Discussant:*     Ronald Jones (University of Rochester).

15.30 - 16.00     Coffee Break.

- 16.00 - 17.30 Michael Rauscher (University of Kiel):  
*Protectionists, Environmentalists, and the Formation of Environmental Policy in an Open Economy.*  
 Discussant: John S. Chipman (University of Minnesota).  
 Achim Körber (SFB 178, Konstanz):  
*Raising Rivals' Costs with Environmental Policy - A Lobbying Approach.*  
 Discussant: Hans Gersbach (University of Basel).

**Wednesday, June 7, 1995**

*Chairman:* Bernd Genser.

- 9.00 - 10.30 Ernst Mohr (University of Kiel, Hochschule St. Gallen):  
*Sustainable Development and International Distribution: Theory and Application to Rainforests as Carbon Sinks.*  
 Discussant: Carsten Schmidt (University of Konstanz).  
 Sebastian Killinger (SFB 178, Konstanz):  
*Decentralized Internalization of International Externalities.*  
 Discussant: Lucas Bretschger (University of Zürich).
- 10.30 - 11.00 Coffee Break.
- 11.00 - 12.30 Ronnie Schöb (University of München):  
*Choosing the Right Instrument: Environmental Policy in the Presence of a Double Dividend.*  
 Discussant: Frank Hettich (SFB 178, Konstanz).  
 Günther Schulze and Rolf Bommer (SFB 178, Konstanz):  
 Economic Integration and Economic Policy. Does NAFTA Increase Pollution?  
 Discussant: Sven Arndt (McKenna College).
- 12.30 - 14.30 Lunch Break.
- 14.30 - 16.00 Albert Schweinberger (SFB 178, Konstanz):  
*Environmental and Commercial Policies in More or Less Populous Open Economies.*  
 Discussant: James R. Markusen (University of Colorado, Boulder).  
 Ruud de Mooij (Ministry of Economic Affairs, The Hague) and  
 Lans A. Bovenberg (University of Tilburg):  
*Environmental Taxation and the Double Dividend: The Role of Factor Substitution and Capital Mobility.*  
 Discussant: Gebhard Kirchgässner (University of St. Gallen).
- 16.00 Closing Address: Heinrich Ursprung (SFB 178, Konstanz).