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TRADE AND POLLUTION LINKAGES: PIECEMEAL REFORM AND OPTIMAL INTERVENTION

by

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RÉSUMÉ

Les liens entre le commerce international et l'environnement local font l'objet d'un examen très attentif tant de la part des chercheurs que de la part des décideurs. Cela est particulièrement le cas dans les pays en développement où le commerce peut être un facteur significatif de changement qualitatif et matériel du niveau de vie. Si les politiques commerciales sont de plus en plus orientées vers la libéralisation, en revanche, les politiques d'intervention servent de plus en plus à corriger les externalités négatives sur l'environnement. Dans un tel contexte, les interactions se produisant entre ces deux types de politiques peuvent être d'une nature complexe et représenter un défi pour les décideurs.

Ce document étudie les aspects de ces politiques de second ordre qui ont une incidence sur les liens entre le commerce et l'environnement. Il déduit les politiques d'intervention optimales et les conditions suffisantes pour une amélioration du bien-être induites par des réformes progressives des politiques de commerce et de protection de l'environnement dans une petite économie. La pollution provenant de la consommation et de la production intérieures est un bien public néfaste. Les niveaux de pollution peuvent être abaissés soit par une diminution de la production, soit par une réduction des taux d'émission de la pollution par unité de production. Modifier les distorsions proportionnellement et vers leur niveau optimal améliore le bien-être.

L'analyse montre les effets spécifiques des droits de douane, des taxes sur la pollution, des taxes à la production et à la consommation sur l'allocation des ressources et sur la pollution. Les politiques ont des effets spécifiques de réduction de la pollution au travers d'une substitution dans la consommation, de la composition de la production et dans la technologie de production qui modifie les taux d'émission. Chaque mesure a des effets contraires sur les possibilités de pollution et de consommation et par conséquent sur le bien-être. Une coordination entre la politique des échanges et la politique de l'environnement apparaît comme une stratégie robuste et met en évidence la nécessité d'une recherche empirique sur les conséquences des différents types d'actions entreprises.

SUMMARY

Linkages between international trade and the domestic environment are receiving intensified scrutiny by researchers and policy makers alike. This is especially the case in developing countries, where trade can be a significant agent of change and growth. While trade policies are increasingly oriented toward lower levels of intervention, interventionist policies are increasingly being implemented to correct for negative environmental externalities. In such a situation, the interactions between the two can be complex and challenging for policy makers.

This paper explores second-best policy issues affecting trade and environmental linkages. We derive optimum policy interventions and sufficient conditions for welfare-improving piecemeal trade and environmental policy reforms in a small economy. Pollution originates in both domestic consumption and production and is a domestic public bad. Production pollution can be abated by decreasing output and/or decreasing effluent rates per unit of output. Changing distortions in proportion to, and toward, their optimal level increases welfare.

The analysis decomposes the specific effects of tariffs, effluent taxes, and production and consumption taxes on market allocation and pollution. Policies have specific incentive effects on pollution abatement via substitution in consumption, output composition and technical production effluent rates which respond to policies. Each policy instrument has opposite effects on pollution and consumption possibilities, and hence on welfare. Co-ordinated environmental and trade policy emerges as a robust approach and makes clear the need for empirical work on the effects of different policy menus.

PREFACE

This Technical Paper, part of the research programme on "Sustainable Development: Environment, Resource Use, Technology, and Trade," analyses the design of piecemeal and coordinated trade and environmental policies, with an eye toward the dual objectives of efficient resource allocation and mitigation of negative environmental externalities.

Linkages between international trade and the domestic environment are a complex and important challenge for policy makers, particularly so in developing countries. Many of these countries are increasingly reliant on trade to raise their material living standards and modernize their economies, and are rapidly liberalizing their trade regimes to achieve fuller participation in international markets. At the same time, particularly in resource-intensive and primary manufacturing industries, this expansion can occasion negative environmental consequences in the absence of corrective policy measures. While trade policies can facilitate more efficient resource allocation for current production, they often omit consideration of short-term environmental externalities and questions of sustainable growth. While environmental regulation can correct for some environmental damage and help get economies on more sustainable growth trajectories, these interventions can introduce undesirable distortions which raise costs to consumers and limit an emerging economy’s competitiveness.

In this work, the authors are helping to lay the conceptual foundation for the more effective coordination of trade and environmental policies required by developing countries. Recognizing the second-best nature of this policy problem, they derive detailed results on piecemeal trade reforms and environmental intervention measures, in each case explicitly decomposing efficiency and welfare effects. This general approach clarifies the basic issues and defines the main criteria for evaluating the costs and benefits of alternative policies. This work is intended to be complementary to a large body of empirical analysis, using detailed general equilibrium models of individual countries, which is being carried out under the same theme of our research programme. Together, it is hoped that this conceptual basis and an extensive set of case studies will significantly improve our understanding of how to reconcile the aspirations for economic growth and a better environment.

Jean Bonvin
President, Development Centre
September, 1994

I. INTRODUCTION

Trade and environment linkages are under increasing scrutiny and a considerable literature is emerging on the subject[1]. Some papers have looked formally at coordination of environmental and trade policy in a polluted open economy (Markusen [1975]; Baumol and Oates [1988]; Krutilla [1991]; Choi and Johnson [1992]; and Copeland [1994]) but, with the exception of Copeland they emphasize optimal interventions and abstract from the more practical issue of designing piecemeal reform. Copeland investigates piecemeal reforms of trade and environmental policy in a small, open, production-polluted, and distorted economy and identifies sufficient conditions for welfare-enhancement. Copeland is an important departure in the well-developed literature on second-best trade reform, following Hatta[2], because it addresses the problem of coordination of environmental and trade policy tools towards "greener" free trade.

Building on Copeland's results, we allow for polluting consumption and production activities and let firms use two approaches to abatement in production. Firms in polluting sectors can decrease output (composition effect) or/and can decrease effluent rates per unit of output (a technique effect). Toxic effluents linked to final consumption are substantial for non-electrical energy and chemicals, for example. Post-consumption waste is another important pollution source[3].

Second, we consider alternative price-oriented instruments including tariffs, consumption and output taxes, and effluent taxes. Effluent taxes may be impractical for developing economies because of monitoring the costs. Output and consumption taxes may provide a more realistic approach to unregulated pollution. Each instrument provides distinct incentives for firms to use one or both abatement strategies. We devote substantial attention to the decomposition of these incentive effects on substitution in consumption, shifting output composition, and "choice of technique" (altering effluent rates)[4].

Identifying and elucidating these effects will clarify two issues in the trade and environment debate. The first is whether trade liberalization induces developing economies to specialize in pollution-intensive activities, particularly for export. Lack of policy coordination or poor instrument choice may explain output and consumption bias towards pollution-intensive goods as well as high effluent rates. The second issue relates to a sobering stylized fact: Although toxic intensity per unit of wealth eventually decreases in high income economies, toxic intensity *per unit of industrial output* increases with growth and remains high in these economies (Hettige, Lucas, and Wheeler [1992]). Our decomposition of abatement via output composition and effluent, combined with analysis of different policy instruments and reforms, sheds light on this intensity question by linking policies to their impacts on pollution intensity and composition.

This paper examines the effects of different policy tools and menus on pollution and allocative efficiency in market goods. We first consider policies aimed at decreasing pollution in the presence of distortions, showing in particular that two welfare effects arise for all reforms. First, the level of pollution is affected. Following the intuition of the targeting principle, the closest instrument, the effluent tax, does the best job in terms of pollution abatement. Production and consumption taxes are the next best, followed distantly by tariffs as the worst environmental policy option. Each instrument has also an indirect effect on allocative efficiency which is often ambiguous analytically. Empirically, for example, lower pollution can mean reduced economic opportunities in developing economies (Lee and Roland-Holst [1993]). The indirect effects of the different instruments on allocative efficiency are more difficult to sign but tend to be of larger magnitude for tariffs than for the other taxes, and smaller for the effluent taxes. However the sum of these effects on welfare is often ambiguous. We also derive and discuss optimum pollution policies for the three types of instrument, holding the trade distortions constant except for the tariff scenario.

Next we combine a piecemeal trade liberalization scenario with pollution reforms, starting from a trade-distorted economy where pollution is previously unregulated, as in many developing economies. In this second series of analyses, we identify a similar dichotomy of direct effects on welfare because of trade and pollution tax reforms and the sum of two indirect effects of lower tariff on pollution and higher pollution taxes on efficiency. These two indirect effects are essentially symmetric. Direct effects are easy to sign for specific cases (such as proportional decreases in tariffs) but the indirect welfare consequences are difficult to determine. Optimal distortions are also derived, along with policy reforms that are welfare-improving (the sum of the direct and indirect effects on welfare is positive); but these very specific scenarios require good knowledge of general equilibrium effects which are likely to be unknown to the policy maker and hence are of limited applicability.

The third purpose of this paper is to motivate more extensive empirical work on trade and pollution linkages. Empirical analysis should quantify the four following welfare effects: the positive direct effect on market efficiency arising from tariff reduction, the positive effect on the environment of introducing pollution taxes, and the two symmetric but ambiguous effects of tariff on pollution and of pollution taxes on market allocation or imports. Such quantification should be explicit about the respective role of consumption substitution, output composition and technique effects.

II. THE BASIC MODEL

Following Hatta (1977), Dixit and Norman (1980), and Copeland (1994), we use a dual treatment of a perfectly competitive and open economy. Pollution is produced by consumers and producers at different rates and all produced pollution accumulates into a public bad. This in turn enters the utility function and the expenditure function of the representative consumer, expressing its disutility and environmental damage, respectively[5]. The derivative of the cost function with respect to pollution is the increase in expenditure necessary to keep utility constant given an increase in pollution.

Given the assumption of a perfectly competitive economy, production decisions are modeled by a revenue or GDP function:

$$R(P + t - b , e, v) = \max_{(x,g)}\{(P + t - b)'x - e\, g'x \mid (x, g) \text{ feasible given inputs } v\} ;$$

where P is the vector of exogenous world prices; t is the vector of trade taxes; e represents the tax on effluents; g is the vector of per unit effluent rates of output x of n commodities; and b is a vector of production taxes/subsidies. The revenue function R is homogenous degree one in prices and taxes[6]. We assume a numeraire good in addition to the n commodities to impose homogeneity[7], and R exhibits all the desired properties. The usual envelope theorem results hold: $R_p = x$; $R_e = - g'x$; R_{pp} is the Hessian of price responses of the output vector x; and R_{ee} is minus the response of production pollution to the effluent tax; R_{pe} = minus the cross-price response of production pollution to output prices; $R_{ep} = R_{pe}'$ and it is the response of output to the effluent tax. For this exposition, our attention is limited to a single pollutant type, but this framework extends without difficulty to a vector of k pollution types (g becomes a kxn matrix and e is a kx1 vector of taxes).

The matrix R_{ee} can be decomposed into three effects, i.e., $R_{ee} = g'R_{pp}\, g + g'(\partial g/\partial p)\, x - x'(\partial g/\partial e)$. The first of these is the output price response holding effluent rates g constant and is positive since R is positive semidefinite. The second effect is that of prices on the effluent rate vector, difficult to sign for individual g_i and dependent on the effluent "production technology", but one can arguably presume that this is positive as well (i.e., $g'(\partial g/\partial p)\, x$ is positive). The last is the effect of the effluent tax on the effluent rate which is negative but preceded by a negative sign. Hence the response R_{ee} is positive and is the sum of three positive components.

The economy has a representative consumer with expenditure function

$$E(P + t + h , e , T , U_0) = \min_{(c, a)} \{((P + t + h)'c + e a'c)| U \geq U_0 \} ;$$

where c represents the consumption vector of n good (we omit the numeraire good); b is a vector of consumption taxes on the same goods; e is the per unit effluent tax applying to pollution in consumption (a'c), a denotes the vector of effluent per unit of consumption of c. As noted, pollution is a scalar and is the sum of different effluent emissions in consumption and production activities but all refer to the same effluent type. Variable T is the public bad (or the variable constrained by a noneconomic target). It is defined as T= a'c + g'x, the sum of consumption and production externalities. Although we focus on one pollutant, the inclusion of consumption externalities and endogenous effluent per unit extends previous work on this subject. We obtain the interesting definitional result that the impact of effluent taxes on trade is equal to the effect of tariffs on pollution ($\partial m/\partial e=\partial T/\partial t$ or $E_{ep}-R_{ep}=E_{pe}-R_{pe}$, with E_{ep} defined below). The scalar U represents utility with a reference level $U_{0.}$ A similar set of derivatives can be obtained for expenditure E as $E_p= c$; $E_e =$ a'c. Here E_{pp} is the Hessian of price responses of the consumption vector c; E_{pe} denotes the cross-price response of consumption pollution to consumption prices; $E_{ep} = E_{pe}'$ is the response of consumption to the effluent tax; and E_{ee} is the response of consumption pollution to the effluent tax.

Similarly, E_{ee} can be decomposed into three effects: $E_{ee} = a'E_{pp} a + a'(\partial a/\partial p)c + c'(\partial a/\partial e)$. It is assumed for the rest of the paper that the consumer does not have the ability to alter the pollution coefficient in the same way as is possible in production. Stylized facts suggest that most of technology-induced abatement is achieved in production and not in final consumption8. Hence the identity reduces to $E_{ee} = a'E_{pp} a$, which is negative. Another derivative, E_T, represents the marginal damage of total pollution on utility or the necessary increase in expenditure to maintain U constant. It is positive. The final derivative of interest is the inverse of the marginal utility of income, E_U, which is positive as well. Derivatives E_U and E_T have derivatives with respect to the consumption price vector and pollution taxes (E_{pU}, E_{eU}, E_{pT} and E_{eT}).

The equilibrium of the economy is described by[9]

(1) $E = R + t'(E_p - R_p) + h'E_p + b'R_p + e(a'E_p + g'R_p)$, with

(2) $T \equiv E_e - R_e = a'E_p + g'R_p$, and with

(3) $m = E_p - R_p$.

Foreign and domestic specific commodities exhibit the same effluent rate. The next section investigates the effect of different policy tools on pollution and allocative efficiency.

III. POLLUTION REFORMS AND OPTIMAL POLICIES

To appraise the environmental and efficiency effects of the policy instruments considered more fully, equations (1) and (2) are totally differentiated with respect to t, e, b, and h. To elucidate the effects of each policy, we start with fixed trade distortions. We first consider changes of effluent taxes, then in production and consumption taxes as a next-best reform, and finally we vary only tariffs to reduce pollution. For each case, we show the direct and indirect effects and examine why effluent taxes are likely to be the best way to abate pollution in a trade-distorted economy.

3.1 Effluent Taxes

Differentiating (1) and (2) for changes in e, holding tariffs constant and assuming h=b=0 yields

(4) $A\,dU = \{[t'(E_{pe}-R_{pe})] + [(e-(P'E_{pT})/(1-E_{eT}))(E_{ee}-R_{ee})]\}\,de,$

with $A=E_U - t'E_{pU} - e'E_{eU} + [(E_T - t'E_{pT} - e'E_{eT})E_{eU}/(1-E_{eT})] > 0$ for stability.

The scalar A represents the general equilibrium inverse of the marginal utility of income or a general equilibrium dE/dU, inclusive of feedback via pollution and trade distortions. $(P'E_{pT})$ is the general equilibrium marginal damage of pollution since $P'E_{pT} = E_T - t'E_{pT} - e'E_{eT} > 0$.

We begin with an effluent tax proportional to the deviations between the general equilibrium marginal damage and the existing tax e (e.g., e is equal to zero or small as in many developing economies): $de=-k(e-(P'E_{pT})/(1-E_{eT}))$. Such a reform has a positive effect on the environment by decreasing pollution. It is measured by $-k\,[(e-(P'E_{pT})/(1-E_{eT}))^2\,(E_{ee}-R_{ee})]$ which is positive. With respect to pollution, this is the best policy type because the effluent tax has three direct component-effects: on x and c holding per unit effluent rate constant; and on effluent rates g via prices and effluent taxes (output and consumption being constant). The indirect effect of the same pollution reform is $-k\,t'(E_{pe}-R_{pe})[e-(P'E_{pT})/(1-E_{eT})]$. This represents the effect of the effluent tax reform on imports. Both E_{pe} and R_{pe} are negative and their difference is ambiguous. If imports contract on average with the introduction of an effluent tax, $t'(E_{pe}-R_{pe}) < 0$, then utility decreases.

The import effect of the pollution tax is through cross-price/tax responses, so it is presumably smaller on average than the effect via price (E_{pp}-R_{pp}). Adding more structure on the sum of these two effects is not sufficient to sign the total indirect effect since it is not known if tariffs are subsidies or taxes. The sum of the direct effect on pollution and the effect on tariff revenues is also ambiguous. With the interpretation of a noneconomic target on maximum pollution, the instrument giving the smallest indirect effect on imports or tariff revenues is the best one for a given pollution target. In the absence of reliable estimates of marginal pollution damage, the latter interpretation may be the most tractable and reasonable although it is likely to yield a negative effect on utility through the indirect effect of effluent taxes on imports.

Assuming a better informed policy maker, the optimal effluent policy can be determined by setting (4) equal to zero. The optimum effluent tax is $e=[-t'(E_{pe}-R_{pe})(E_{ee}-R_{ee})^{-1}] + \{[P'E_{pT})/(1-E_{eT})]\}$. This optimum policy equates the effluent tax to the general equilibrium marginal damage of pollution, minus the feedback effect on welfare of the tax. Any pollution policy reform introducing effluent taxes such that $de = k\ [-t'(E_{pe}-R_{pe})(E_{ee}-R_{ee})^{-1}]+\{[(P'E_{pT})/(1-E_{eT})]$ will be welfare-improving as well since (E_{ee}-R_{ee}) is negative in this case and would be negative semidefinite if pollution were represented by a vector.

3.2 Production and Consumption Taxes

Now consider reform via production and consumption taxes, b and h, assuming effluent taxes are not available and no distortions other than tariffs exist. The comparative statics corresponding to that scenario are

(5) $BdU= \{(t+h)'E_{pp} -(P'E_{pT})/(1-E_{eT}))E_{ep}\}\ dh+\{(t-b)'R_{pp} -((P'E_{pT})/(1-E_{eT}))R_{ep}\}db,$

with $B=P'E_{pU} + [(P'E_{pT})\ E_{eU}/(1-E_{eT})] > 0$ for stability.

Starting from zero tax levels, consider the introduction of taxes proportional to the pollution induced by the consumption and output vectors mimicking the previous effluent tax reform $dh=a'k((P'E_{pT})/(1-E_{eT}))$ and $db=g'k((P'E_{pT})/(1-E_{eT}))$. The direct effect of this consumption and production tax reform is $-(P'E_{pT})/(1-E_{eT}))E_{ep}a(k((P'E_{pT})/(1-E_{eT})))$ for the consumption tax, and $-(P'E_{pT})/(1-E_{eT}))R_{ep}g(k((P'E_{pT})/(1-E_{eT})))$ for the production tax.

We abstract from consumption effluent rate dependence on prices or taxes so that $E_{ep}a=E_{ee}<0$. That is, the effect of the consumption tax is similar to the effect of the effluent tax on consumption-induced pollution. In a more general case, it would be smaller if account were taken of incentive effect of effluent taxes on consumption effluent rates per unit. In any case, the interesting insight here is the substitution effect in consumption that parallels the output composition effect.

The effect of production taxes on production pollution is smaller than for the effluent tax since the production tax only captures $-R_{eP}g$, which is less than R_{ee} since $R_{ee}=-g'R_{pe}-x'\partial g/\partial e$. So the production tax captures two of the three effects of effluent taxes omitting the important effect of effluent taxes on effluent intensity ($\partial g/\partial e$). Hence product taxes mimic effluent taxes but are less effective in terms of overall pollution abatement.

The indirect effects of these taxes on imports (t'm) are $kt'E_{pp}\,a\,((P'E_{pT})/(1-E_{eT}))$ for h, and $kt'R_{pp}\,g(((P'E_{pT})/(1-E_{eT})))$ for b. For the consumption component, the impact on imports or tariff revenues is similar to the effluent tax, a result reinforced by the assumption of fixed pollution coefficients a. For the production component noting that ($g'R_{pp} = -R_{ep}- x'\partial g/\partial p$) the effect of db on the output vector is likely to be smaller on average than for an effluent tax because of the additional impact of the production tax on effluent rates ($x'\partial g/\partial p>0$). The sum of the two indirect components on consumption and production is also ambiguous. It is nevertheless equal to the indirect effect of the effluent tax plus $(-t'(\partial g/\partial p)x)$ which would in all likelihood decrease welfare further[10].

Optimal consumption and production taxes are found by setting dU/db=dU/dh=0 in (5) which yields two sets of equations that are solved for the optimum tax vectors. They are $h= -t'+(P'E_{pT})/(1-E_{eT}))a$, and $b= t'-((P'E_{pT})/(1-E_{eT}))R_{ep}\,R_{pp}^{-1}$. We assume that E_{pp} and R_{pp} are full rank. Note that the optimum consumption tax vector mimics the effluent tax since it is related to the marginal damage of pollution but it directly offsets the presence of tariffs. The production taxes are less effective for abatement since other things being equal they "overshoot" the level of optimum effluent tax, i.e., $b= t'+((P'E_{pT})/(1-E_{eT}))(g + x'(\partial g/\partial p)R_{pp}^{-1})$. Note our corrective mechanism is derived for each tariff distortion. Any pollution reform undertaken with the introduction of consumption and production taxes that are proportional to these optimal levels would be welfare-enhancing, since E_{pp} is negative semidefinite and R_{pp} is positive semidefinite.

3.3 Tariffs

The last pollution reform uses tariff changes to reduce pollution. The comparative-statics of tariff reforms, dt, are

(6) $A\, dU = \{[t'(E_{pp}-R_{pp})] + [(-(P'E_{pT})/(1-E_{eT}))(E_{ep}-R_{ep})]\}\, dt$,

with $A=E_U - t'E_{pU} + [(E_T - t'\, E_{pT})\, E_{eU}/(1-E_{eT})] > 0$ for stability.

Equation (6) shows the difficulty of achieving pollution abatement with tariffs. Tariffs impose a tax on consumption with a corresponding subsidy on production leading to offsetting pollution effects for goods with both consumption and production externalities. To reach a given pollution target it may be virtually impossible to design a tariff policy reform short of prohibitive tariffs that annihilate exports or output in some sectors.

For the sake of discussion assume that production pollution is the largest contributor to T and that it is the reform objective. Consider $dt = -\, k(P'E_{pT})/(1-E_{eT}))g$. Hence the tariff behaves like a production tax proportional to effluent rates in production. We obtain the following direct effect on pollution: $k\, ((P'E_{pT})/(1-E_{eT}))(E_{ep}-R_{ep})\; g((P'E_{pT})/(1-E_{eT}))$ which is negative if the effect of the tariff on production pollution is larger than the effect of the tariff on consumption pollution. The latter effect is induced by implicit consumption subsidies due to the tariff reform. Hence tariffs do not allow for specific policy intervention in consumption and production the way effluent, consumption and production taxes do. Besides this major handicap, tariffs share the same shortcoming as product taxes with respect to abatement incentives on effluent rates ($x'\partial g/\partial e$).

The effect of tariff reform on imports is the most immediate, via the price response of imports (E_{pp}- R_{pp}). The off-diagonal elements of the price response matrix cannot be signed with any generality. It is difficult to quantify *a priori* the utility loss induced via (t'dm) with the tariff change.

The last policy issue is the optimal tariff. By setting (6) equal to zero we obtain the optimum tariff vector $t= [(P'E_{pT})/(1-E_{eT})][a'E_{pp}+g'R_{pp}+x'(\partial g/\partial p)](E_{pp}-R_{pp})^{-1}$. The vector of optimum tariffs is different from zero reflecting the pollution public bad or target and is related to the marginal damage of pollution, representing a compromise between pollution abatement in production and consumption. If the vector of price responses of pollution, $(\partial T/\partial p)$, has both positive and negative elements it is not clear that tariffs can successfully move total pollution to an optimum or targeted level. This ambiguity is a prime motivation for more empirical work on trade and environmental linkages. Table3.1.a summarizes the various efficiency and environmental implications derived in this section on environmental policy reform.

IV. JOINT TRADE AND POLLUTION REFORMS

This section considers two types of reforms simultaneously: trade liberalization and pollution targeting first with effluent taxes, then with product taxes. Again here indirect and direct effects arise from both policy instruments. The indirect effects are symmetric and difficult to sign *a priori*. The optimum policy mix for the two sets of instruments is also derived.

4.1 Tariffs and Effluent Taxes

The comparative-statics of joint tariff reduction with introduction of effluent taxes are

(7) $A\,dU = \{[t'(E_{pe}-R_{pe})] + [(e-(P'E_{pT})/(1-E_{eT}))(E_{ee}-R_{ee})]\}\,de$

$+ \{[t'(E_{pp}-R_{pp})] + [(e-(P'E_{pT})/(1-E_{eT}))(E_{ep}-R_{ep})]\}\,dt,$

with $A=E_U - t'E_{pU} - e'E_{eU} + [(E_T - t'\,E_{pT} - e'E_{eT})E_{eU}/(1-E_{eT})] > 0$ and assuming that e=0 prior to the reform. Now assume that dt = -kt, and that $de=k[(P'E_{pT})/(1-E_{eT})]$, which correspond to proportional tariff reductions and an effluent tax proportional to and towards the general equilibrium marginal damage of pollution. The direct effect of the trade reform on utility is $-kt'(E_{pp}-R_{pp})t$ which is positive since the Hessian of import demand price responses is negative semidefinite. The direct effect of effluent taxes on pollution abatement is $\{[-k\,(P'E_{pT})/(1-E_{eT})]^2(E_{ee}-R_{ee})\}$ which is also positive.

The corresponding indirect effects are $kt'(E_{pe}-R_{pe})(P'E_{pT})/(1-E_{eT})$ and they are symmetric because they show the impact of tariffs on pollution or the effect of the effluent tax on imports, $(E_{ep}-R_{ep}=\partial T/\partial t=\partial m/\partial e)$. The sign of these effects is again ambiguous, reaffirming the need for empirical work to assess the effects of joint reforms realistically.

If the two policy instruments can be freely implemented, then their optimum levels are obtained by setting dU/dt=0 and du/de=0. This yields t = 0, and e= $(P'E_{pT})/(1-E_{eT})$ assuming $((E_{pp}-R_{pp}) -(E_{pe}-R_{pe})(E_{eT})^{-1}(E_{ep}-R_{ep}))$ is of full rank. Hence the optimum policy mix is the standard result of free trade and an effluent tax equal to the general equilibrium marginal damage of pollution.

4.2 Tariffs, Production and Consumption Taxes

The second scenario for joint reform is tariff reduction accompanied by the introduction of taxes in consumption and production. Consider proportional changes i.e., dt=-kt, dh= $k((P'E_{pT})/(1-E_{eT}))a$, and db= $k((P'E_{pT})/(1-E_{eT}))g$. According to the individual effects of each policy (obtained in the previous section), the tariff reform includes a positive utility effect and an ambiguous indirect pollution impact. Likewise the production and consumption taxes bring positive environmental impacts but ambiguous indirect effects on imports. The two indirect effects are cumulative but not symmetric, as it was in the previous case, since the pollution tax here does not have the incentive effect on effluent rates ($\partial g/\partial e$). The impact of tariff reduction on pollution will be larger than the indirect effect of consumption and production taxes on welfare via imports.

Optimum tariff, production and consumption tax vectors are found by setting dU/dt=0, dU/db=0, and dU/dh=0. The optimal tariff would be zero since it is redundant with the consumption and production taxes which are h= $((P'E_{pT})/(1-E_{eT}))E_{ep} E_{pp}^{-1}$ and b= $-((P'E_{pT})/(1-E_{eT}))R_{ep} R_{pp}^{-1}$. Except for the tariff correction, they are equal to the optimum taxes described in the section on pollution policy reform. Table 3.1.b summarizes the various efficiency and environmental implications derived in this section on joint reforms.

The evidence gathered in Lee and Roland-Holst (1993) shows that welfare improvements are bigger when both policy instruments are used simultaneously with tariffs set optimally to zero. Pollution taxes for a given pollution target have a larger detrimental effect on welfare than combined trade and pollution reform has for the same pollution abatement target. The welfare gains from lower tariffs offset some of the welfare loss on imports induced by the pollution taxes.

TABLE 3.1

Efficiency and Environmental Impact of Piecemeal Reforms

3.1.a. Environmental Policy Reform

Instrument	Effect on Efficiency	Effect on Pollution Abatement
Effluent tax	Indirect, small sectoral effects ambiguous in aggregate	Positive, on composition and technique
Production and Consumption taxes	Large sectoral effects ambiguous in aggregate, more likely negative than effluent tax	Positive, on composition partial on technique more
Tariff	Large sectoral effects ambiguous in aggregate, more likely negative than effluent taxes	Indirect, ambiguous, abatement potentially not feasible, partial effect on technique

3.1.b. Joint Trade and Environmental Reform

Instruments	Effects on Efficiency	Effects on Pollution Abatement
Tariff combined with	Positive direct	Ambiguous in aggregate, indirect effect on pollution
effluent tax	Indirect, ambiguous in aggregate small sectoral effects (symmetry $\partial m/\partial e=\partial T/\partial t$)	Direct and positive full technique effect
Tariff combined with	Positive direct	Ambiguous in aggregate, indirect effect on pollution
production and consumption taxes	Ambiguous in aggregate, large sectoral effects	Positive, less effective than effluent tax, partial technique effect

V. CONCLUSIONS

This paper explored second-best policy issues affecting trade and environmental linkages. We derived sufficient conditions for welfare-improving piecemeal trade and environmental policy reforms in a small polluted economy. Pollution, a public bad, originates in both consumption and production, the latter being decomposed into composition and technique effects. Moving distortions proportionally to and toward their optimal level increases welfare monotonically. The analysis emphasized specific effects of tariffs, effluent taxes, production and consumption taxes on market allocation and pollution and through substitution in consumption, changes in output composition and choice of technique. Effluent taxes have the most direct effect on toxic intensity with limited indirect effects on imports, or in other words, on utility of consumption. A progressive policy switch away from "command and control" policies towards effluent taxes may be a key element in decreasing toxic intensity. However the relative contribution of the two types of abatement (composition and technique) remains an empirical question.

Trade policy reforms increase feasible consumption, but have indirect effects on pollution. Co-ordination of pollution and trade policies is important because the two indirect effects may potentially completely offset the direct beneficial effects of the reform. When policies are set to or changed in proportion to their optimal levels, the aggregate welfare (consumption *cum* pollution abatement) outcome is positive, but in practice, signing the welfare effects of co-ordinated trade and environmental policies is an empirical task.

The theoretical results in this paper are intended to strengthen conceptual foundations for the extensive empirical work which is ultimately required to support coherent policies towards trade and the environment. Although some general conclusions have been drawn, it is clear that linkages between economic efficiency and environmental values are complex, and policies to promote and reconcile the two must be designed and implemented with care. As emphasized in Lee and Roland-Holst (1993), and Beghin et al. (forthcoming), a detailed sectoral modeling and estimation are essential to the enterprise. Future work should include sector-specific programme evaluation in a general equilibrium framework, especially in a few sectors where the trade/environment nexus is prominent (e.g., agriculture, energy). Without detailed empirical support of this kind, it is unlikely that policy makers, relying on intuition and rules-of-thumb alone, will achieve welfare improvement or, even less, anything close to optimality.

NOTES

1 Several recent survey papers using different taxonomies examine "trade and environment" linkages (e.g., Cropper and Oates; Dean; and Beghin, Roland-Holst, and van der Mensbrugghe (1994)).

2 See Vousden, chapter nine, for a survey of many of these second-best results.

3 Copeland's model is recursive because policy impact on pollution can be solved independently of pollution effects on utility. Our specification considers feedback effects of utility on pollution (the "scale" income effect of Grossman and Krueger).

4 Grossman and Krueger suggested this categorization of pollution effects. Copeland and Taylor model trade and environment linkages following that decomposition. Their definition of composition refers to the range of goods produced within a continuum. Our definition refers to different output "baskets" of a fixed number of commodities.

5 Alternatively pollution can enter the expenditure function of the economy even if it is not valued directly but if it is constrained from above by a noneconomic target.

6 R satisfies other properties (convex in prices and effluent taxes, increasing in prices, decreasing in effluent taxes and the feasible technology set underlying R is convex). We refer readers to Hatta and Dixit and Norman for more details on revenue and expenditure functions.

7 The numeraire could be a nontraded good. Modeling the economy with many nontradables would require in an additional assumption, i.e, substitution in excess demand between nontradables and tradables, to sign the efficiency and pollution impacts of reforms. Nontradables would also dampen the effectiveness of tariffs to decrease pollution by encouraging imports of dirty production.

8 Modeling and implementing endogenous effluent rates in consumption may be more difficult than in production. In production we have or can develop good data on intermediate consumption (inputs), and on effluent linked to these inputs (Dessus *et al*.). Substitution between value added (labor and capital) and these intermediates inputs allows for lower effluent rate per unit of output. This approach has no obvious counterpart in consumption. This implementation problem motivates our simplifying assumption.

9 The trade balance equation in this model is redundant by Walras' law, and is omitted.

10 This conjecture assumes that the economy is distorted with positive tariffs and that effluent rates increase in average with prices.

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