Environment and Development Economics 2 (1997): 5–18

Theory and Applications

Regional integration and the environment*

ARVIND PANAGARIYA
Center for International Economics, University of Maryland, College Park, MD 20742, USA
E-mail: panagari@econ.umd.edu

SETHAPUT SUTHIWART-NARUEPUT
Policy Research Department, The World Bank, 1818 H St NW, Washington, DC 20433, USA
E-mail: ssuthiwartnaruep@worldbank.org

ABSTRACT. This paper explores the interaction between regional integration and the environment in a formal three-country, three-good model which incorporates pollution. Our main findings are: (1) whether preferential trading improves welfare depends critically on the level of domestic pollution charge extant and the direction of trade; (2) the introduction of preferential trading may lower welfare even when the pollution policy is chosen optimally; and (3) coordination of environmental policies only makes sense when pollution is transnational.

Regional integration arrangements (RIAs) have become increasingly popular among both developed and developing countries across the globe. They include the North American Free Trade Agreement (NAFTA) and MERCOSUR in the Americas; the Southern African Customs Union; country-specific free trade arrangements with the European Union in northern Africa; and ongoing free trade agreement discussions in Asia. At the same time, environmental issues have also assumed greater prominence in economic policy discussions. As the RIAs become effective, what is the impact on polluting sectors and the environment? That environmental issues are an important consideration in RIAs was recently underlined by the inclusion of a side agreement on environmental standards in the NAFTA. It is possible that future regional integration schemes will continue to assign an important role to environmental issues.

The increased importance of environmental issues in the context of mul-

---

* The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent.

tiplying regional arrangements gives rise to two issues of analytic interest. First, what implications does the inclusion of environmental pollution into the traditional analysis have for the welfare economics of regional integration? Implementation of regional arrangements impacts the output mix which, in turn, influences the level of pollution in the member countries. Because pollution affects welfare, the traditional results on preferential trading are likely to alter. Second, is there a case for inclusion of environmental policies in free trade area arrangements? If yes, under what circumstances and if not, why not? Issues of this type are likely to be important in the context of most future regional arrangements.

In this paper, we explore the interaction between regional arrangements and environmental pollution in a formal model and take a first stab at the issues just mentioned. Because the interactions are complex, we choose a simple model capable of capturing the essence of the problem. We also proceed in small, incremental steps to sort out systematically the various forces at work.

Our analysis is based on the small-union Meade model. Though Meade (1955) himself had worked with a model with fully flexible terms of trade, following Lipsey (1958), the large body of literature on the Meade model which has developed subsequently has focused almost exclusively on the small-union assumption (e.g. Corden, 1976; McMillan and McCann, 1981; Lloyd, 1982).[1]

The Meade model envisages a world consisting of three countries and three goods. Each country exports one and imports the other two goods. Starting from non-discriminatory tariffs on partner countries, two countries form a preferential trading area by lowering the tariffs on each other's goods while retaining the tariffs on the third country. The countries are small in relation to the third country in the sense that the terms of trade are determined in the latter. In this setting, if excess demands exhibit substitutability, the introduction of preferential trading is necessarily welfare-improving.

The first step in our analysis is to introduce environment into this model. In conformity with the conventional literature on environment (e.g. Baumol and Oates, 1988), we model pollution as a factor of production on the supply side. What makes pollution interesting from an analytical standpoint is that it plays two different roles. It functions as an input into production and also a public 'bad' in consumption. The effect of incorporating pollution into our analysis of preferential trading arrangements is best understood if each of these roles is considered separately in turn.

To highlight the role of pollution as an input, it is helpful to focus first on a model in which pollution can be disposed of entirely at a constant cost and it is beneficial to do so. This is equivalent to thinking of pollution as an input which can be purchased from the third country at a fixed price. This initial set-up allows us to suppress the role of pollution as a public 'bad',

---

[1] Because Meade himself focused on the welfare implications of preferential trading for *global* welfare, he was able to retain flexible terms of trade without the complications which arise when the focus of the analysis is either a union member or the union as a whole. For details see Panagariya (forthcoming).

enabling us to sort out clearly how the production side of the economy is modified when pollution plays the role of an input.

Our next step is to incorporate the second role of pollution. We consider its deleterious effects on utility and replace the assumption of complete disposal of pollution at a constant price by introducing costs of pollution in terms of lost utility. This more complete model is then used to analyse the interaction between preferential trading and pollution standards. Initially, we consider 'national' pollution, but later we introduce transnational pollution. Our analysis follows the modern dual approach popularized by Dixit and Norman (1980). Recently, Panagariya *et al.* (1993), Copeland (1994) and Lopez (1994) have used this approach to study the interaction of trade policy and environment in different contexts.

Our results can be summarized as follows. First, in the presence of pollution, the Meade result need not hold. Whether the result holds depends critically on (i) the level of extant domestic pollution charge, and (ii) the direction of trade. If the pollution charge is too low and the country exports the product which generates pollution, welfare may decline upon the introduction of preferential trading. Second, even if the pollution policy is chosen optimally, the introduction of preferential trading may lower welfare. Thus, setting the environmental policy optimally is not sufficient to ensure the validity of the Meade result. Finally, coordination of environmental policies within a regional arrangement makes sense only if pollution is transnational, though not global. Not surprisingly, when pollution is strictly national, each country is better off setting up its environmental policy in isolation.

The paper is organized as follows. Section 1 introduces the Meade setup used in the paper. As already noted, to focus on its role as an input, it is assumed that pollution can be disposed of at a fixed cost without affecting utility. Section 2 incorporates the second role of pollution by introducing it into the utility function. Section 3 considers preferential liberalization under optimal pollution policies. Transnational pollution is analyzed in section 4. Section 5 concludes.

1. The Meade model with pollution as a pure input

Let there be three countries, A, B and C, and three commodities, 1, 2 and 3. Commodity 1 is exported by A, 2 by B and 3 by C. Each country imports the two commodities it does not export. A and B are potential members of a preferential trading arrangement. Both are small in the sense that they take external prices, determined in C, as given. Because we intend to hold the world prices fixed throughout the paper, by appropriate choice of units, we set them all equal to 1.

The standard approach in the literature is to model pollution as an input in the production of one or more goods. *Ceteris paribus*, the larger the amount of pollution, the larger the output of the good.[2] Because pollution inflicts a cost on consumers through a loss of utility, polluting firms are subject to a charge. The model with which we eventually wish to work is

---

[2] Strictly speaking, the input is clean air. But the common practice is to enter pollution in the production function.

constructed along these lines. However, as noted in the introduction, from an expositional standpoint it is convenient to begin with a simpler model in which pollution plays only the role of an input and does not affect utility directly. Instead, pollution is disposed of entirely at a constant (social) cost per unit. An analytically equivalent assumption is to say that pollution is like a traded input available from the third country at a fixed price. Because this problem has not been considered in the literature so far, it is worthy of analysis in its own right.[3]

We outline country A's economy in detail. Country B's economy can be constructed by analogy. As far as possible, we use lower-case letters to represent the variables of country A. A exports 1 and imports 2 and 3. Each good uses a sector-specific factor and labour. In addition, good 2 uses pollution which the government disposes of at a constant social cost per unit of pollution (measured in terms of the numeraire good) denoted $\tilde{p}$. The government charges a price for this service which may or may not coincide with $\tilde{p}$. If we think of pollution as an imported input, $\tilde{p}$ is the border price which, if subject to a tariff, differs from the price paid by firms. The quantity of pollution is denoted z. The initial tariff on good i is denoted t_i ($i = 1, 2, 3$). If good i is exported, the tariff rate is 0 (i.e., $t_1 = 0$). We let τ denote the proportionate divergence between the per-unit social cost of disposal of pollution and the charge imposed on firms. (If pollution is viewed as an imported input, τ is the *ad valorem* tariff on it.) Thus, the domestic price of good i is $1 + t_i$, and the pollution charge paid by producers is $(1 + \tau)\tilde{p}$.

Assuming perfect competition in all markets, the outcome on the supply side can be represented by the following problem.

$$\text{Max}\ [f_1(s, l_1) + (1 + t_2)f_2(k, l_2, z) + (1 + t_3)f_3(g, l_3) - (1 + \tau)\tilde{p}z]$$
$$\text{subject to } l_1 + l_2 + l_3 = l,$$

where the choice variables are $l_i (i = 1, 2, 3)$ and z. The $f_i(\cdot)$ are production functions for goods i and are linear homogeneous in their arguments. s, k and g, respectively, stand for skilled labour, capital and land endowments available in A. These factors are assumed to be specific to sectors 1, 2 and 3, respectively. The solution to the above yields a revenue function $r(1, 1 + t_2, 1 + t_3, h, v)$ where $h \equiv (1 + \tau)\tilde{p}$ and $v \equiv \{s, k, g, l\}$. Because factor endowments are to be held fixed in this section, we suppress v from the revenue function. Observe that h is the pollution charge (or domestic price of the imported input). The revenue function has the usual properties. We denote by r_i ($i = 1, 2, 3$) the partial derivative of $r(\cdot)$ with respect to the ith good and by r_h the partial derivative with respect to h. Then, by the envelope theorem, $r_i = f_i$ and $r_h = -z$. The former are supplies of goods i, and the latter the demand for pollution as an input.

Remembering that pollution is disposed of entirely or is an imported input, it does not enter the utility function. Therefore, the demand side of

---

[3] There is a general dearth of literature on the implications of imported inputs for the customs union theory. Though Meade (1955) himself paid some attention to the role of inputs, the subsequent literature has focused almost exclusively on final goods.

the economy can be represented by a standard expenditure function $e(1, 1 + t_2, 1 + t_3; u)$ where u stands for utility. Assuming that all tariff revenue and pollution charge not used up to cover the clean-up costs are redistributed in lump-sum fashion, the economy's budget constraint implies

$$e(1, 1 + t_2, 1 + t_3; u) = r(1, 1 + t_2, 1 + t_3, h) + \sum_{i=2}^{3} t_1(e_i - r_i) - \tau\tilde{p}r_h. \quad (1)$$

To analyse the effects of changes in trade policy variables, it is convenient to work with net expenditure function defined as the excess of expenditure over revenue:

$$m(1, 1 + t_2, 1 + t_3, h; u) \equiv e(1, 1 + t_2, 1 + t_3; u) - r(1, 1 + t_2, 1 + t_3, h).$$

The budget constraint (1) can now be rewritten as

$$m(1, 1 + t_2, 1 + t_3, h; u) = t_2 m_2(\cdot) + t_3 m_3(\cdot) + \tau\tilde{p}m_h \quad (1')$$

where m_i denotes the partial of $m(\cdot)$ with respect to the price of good i, and m_h the partial with respect to the domestic price of pollution. In view of our definition of $m(\cdot)$, we have $m_h = -r_h$.

We are now ready to analyse the effect of the introduction of preferential trading. Suppose A lowers the tariff on B, t_2, without lowering the tariff on C. Differentiating (1′) with respect to t_2 and simplifying, we obtain

$$n\frac{du}{dt_2} = t_2 m_{22} + t_3 m_{32} + \tau\tilde{p}m_{h2} \quad (2)$$

where, assuming all goods are normal in consumption, $n \equiv m_u - t_2 m_{2u} - t_3 m_{3u} > 0$. The first two terms on the right-hand side of (2) are the usual trade creation and diversion terms: a reduction in t_2 increases imports of 2 which is trade creation, but reduces those of 3 which is trade diversion. We expect m_{2h} ($\equiv -r_{2h} = \partial z / \partial(1 + t_2)$) to be positive: an increase in the price of good 2 which expands production of 2 increases the demand for pollution as an input. The third right-hand-side term is therefore positive and reflects *pollution-induced trade diversion*. A decrease in t_2 decreases the output of 2, reduces the demand for pollution as an imported input, and lowers tariff revenue. As we shall see, this term may potentially reverse the Meade result.

We now proceed to sign the right-hand side of (2). Since $m(\cdot)$ is homogeneous of degree one in prices, $m_2(\cdot)$ is homogeneous of degree zero in the latter. Remembering that $h \equiv (1 + \tau)\tilde{p}$, we have

$$m_{21} + (1 + t_2)m_{22} + (1 + t_3)m_{23} + (1 + \tau)\tilde{p}\, m_{2h} = 0.$$

Substituting the above into (2) and manipulating, we obtain

$$n\frac{du}{dt_2} = \frac{1}{1 + t_2}\left((t_3 - t_2)m_{23} - t_2\left[m_{21} + (1 + \tau)\tilde{p}\, m_{2h}\right]\right) + \tau\tilde{p}\, m_{2h}. \quad (2')$$

Because we wish to analyse the effect of the introduction of preferential trading, we evaluate the effect at $t_2 = t_3$. Making this substitution and simplifying, we have

$$n\frac{du}{dt_2} = \frac{1}{1+t_2}\,[-t_2 m_{21} + m_{2h}\tilde{p}(\tau - t_2)]. \tag{3}$$

With τ set equal to t_2, the right-hand side of (3) reduces to the usual expression obtained in the Meade model. The assumption of substitutability ensures $m_{21} > 0$ and, given $t_2 = \tau$, we obtain $du/dt_2 < 0$; a reduction in the tariff on imports from the partner country below that charged on imports from the outside country improves welfare. Intuitively, given $t_2 = \tau = t_3$, the marginal distortion in sectors 2 and 3 in both consumption and production is the same. Given net substitutability, the reduction in t_2 increases exports of good 1 and imports of good 2 but reduces the imports of good 3. Given the rise in exports, the increase in imports of good 2 is larger than the reduction in imports of good 3. With equal marginal distortion in sectors 2 and 3, the gain from increased imports of 2 is larger than the loss from reduced imports of 3.

The Meade result can break down, however, if τ differs from t_2. With m_{2h} positive, $\tau > t_2$ implies that the second term within square brackets is positive and contributes negatively to welfare when t_2 is reduced. For a sufficiently large value of τ, the Meade result is reversed. The intuition for this result stems from the role of pollution as an input. With $\tau > t_2 = t_3$, the effective protection to good 2 is lower than that to good 3. Put differently, since $\tau \equiv t_2 + (\tau - t_2)$, sectors 2 and 3 are both protected at rate $t_2 = t_3$ but, in social terms, sector 2 is subject to an additional production tax at rate $\tau - t_2$. When we lower t_2, the distortion due to effective protection at rate $t_2 = t_3$ is reduced as in the previous paragraph but the distortion due to the production tax $(\tau - t_2)$ is increased. The net effect on welfare is ambiguous. In the opposite case when $\tau < t_2 = t_3$, goods 2 and 3 can both be viewed as being protected at rate $t_2 = t_3$ plus a production subsidy to 2 at rate $t_2 - \tau$. The reduction in t_2 now reduces the subsidy at the same time that it reduces the distortion due to protection. The two effects are mutually reinforcing and welfare improves necessarily.

2. The model with domestically generated pollution

The preceding discussion highlighted the role of pollution as an input and its implications for preferential trading arrangements. We are now in a position to consider its additional disutility role. In this section, rather than assume that pollution can be disposed of at a constant social cost, we introduce the more realistic assumption that pollution affects utility directly. We continue to assume that firms can pollute as much as they want provided they pay the fixed charge per unit of pollution. Because residents incur a utility cost of pollution, the latter enters into the expenditure function which is now written $e(1, 1 + t_2, 1 + t_3; z, u)$.[4]

In this set-up, the economy's budget constraint is given by

$$m(1, 1 + t_2, 1 + t_3, h; z, u) = t_2 m_2(\cdot) + t_3 m_3(\cdot) + h m_h. \tag{4}$$

Note that, because no costs are being incurred to dispose of pollution now,

---

[4] The consumer's problem is to minimize $\sum(1 + t_i)c_i$ subject to $W(c_1, c_2, c_3; Z) = u$ where $W(\cdot)$ is the utility function and the c_i are quantities of i consumed.

the entire proceeds from pollution hm_h ($=hz$) are redistributed to consumers. Of course, consumers are penalized through pollution in return for this transfer. From the properties of the revenue and import functions

$$z = -r_h(\cdot) = m_h(\cdot). \tag{5}$$

Consider now the effect of a change in t_2. Differentiating (4) with respect to t_2 and simplifying, we have

$$n\,du = (t_2m_{22} + t_3m_{32} + hm_{h2})dt_2 - (m_z - t_2m_{z2} - t_3m_{z3})dz. \tag{6}$$

Here n is defined as before. Making use of (5), we have

$$dz = -r_{h2}dt_2 \equiv m_{h2}dt_2. \tag{7}$$

This equation allows us to rewrite (6) as

$$n\frac{du}{dt_2} = t_2m_{22} + t_3m_{32} + \{h - (m_z - t_2m_{z2} - t_3m_{z3})\}m_{h2}. \tag{6$'$}$$

To explain (6′) and relate it to Equation (2), let us first define the marginal social cost of pollution. If we increase pollution by one unit, the consumer must be given e_z in order to hold his utility unchanged. Of course, a unit increase in z increases imports of goods 2 and 3 by m_{2z} and m_{3z}, respectively, which in turn increases tariff revenue by $t_2m_{2z} + t_3m_{3z}$. If goods 2 and 3 exhibit substitutability with clean air, $t_2m_{2z} + t_3m_{3z}$ is positive, and if they exhibit complementarity it is negative. Because $e_z = m_z$, the net social cost of an extra unit of pollution can be represented by

$$\tilde{p} \equiv m_z - t_2m_{2z} - t_3m_{3z}. \tag{8}$$

Instead of $\tilde{p}$ representing the cost of disposing of pollution, we now use $\tilde{p}$ to denote the marginal social cost of obtaining one unit of pollution domestically. Given that m_z ($=e_z$) is linear homogeneous in goods prices, we have $m_z = m_{z1} + (1 + t_2)m_{z2} + (1 + t_3)m_{z3}$. Making use of this relationship, we can rewrite (8) as

$$\tilde{p} \equiv m_{1z} + m_{2z} + m_{3z} \tag{8$'$}$$

Thus, if all import demands exhibit net substitutability with clean air, $\tilde{p}$ is necessarily positive. Of course, from (8), if import demands for goods 2 and 3 exhibit complementarity ($m_{2z}, m_{3z} < 0$), $\tilde{p}$ is positive as well. Finally, under free trade, $\tilde{p} = m_z > 0$. Only if there is net complementarity between m_1 and z, and net substitutability between m_2 and m_3 on the one hand and z on the other, can $\tilde{p}$ be negative. We will exclude this possibility by assumption.

In general, there is no reason for h to equal $\tilde{p}$. Letting τ now denote the proportionate divergence between the market price and social cost of pollution, we can write

$$h = (1 + \tau)\tilde{p}. \tag{9}$$

Substituting from (8) and (9) into (6′), we obtain the same expression as the right-hand side of Equation (2). Thus, once we define the social marginal cost of pollution properly, we obtain a one-to-one correspondence between the results in this and the previous section.

The analogy between the analyses in the two sections can be taken one step further. Exploiting the homogeneity properties of $m(\cdot)$, setting $t_2 = t_3$, and proceeding as before, we obtain

$$n\frac{du}{dt_2} = \frac{1}{1+t_2}\left[-t_2 m_{21} + m_{h2}\{h - (1+t_2)(m_z - t_2 m_{z2} - t_3 m_{z3})\}\right] =$$

$$\frac{1}{1+t_2}\left[-t_2 m_{21} + m_{h2}\{(1+\tau)\tilde{p} - (1+t_2)\tilde{p}\}\right] \tag{10}$$

where we use (8) and (9) to obtain the second equality. Thus, (10) and (3) are shown to be equivalent.

To obtain equivalence between the small-union Meade model and that in the previous section, we set $t_2 = t_3 = \tau$. This equality ensured that the distortion in sector 2 as measured by the effective rate of protection was equalized with the distortion in sector 3. The equality of these distortions gave us equivalence with the Meade model. This same equivalence is obtained in the present model if we equate the divergence between the price of pollution facing producers and the social marginal cost of pollution to t_2 $(=t_3)$. Thus $\tau = t_2$ leads to $h = (1+t_2)\tilde{p}$ which, given (8), reduces the term in the curly brackets in Equation (10) to zero, and the right-hand side of (10) to the expression in the standard small-union Meade model.

If the price of pollution is distorted more than the tariff on imports (i.e., $\tau > t_2 = t_3$ or $h > (1+t_2)\tilde{p}$), preferential trading may or may not improve welfare. Intuitively, with the pollution charge set too high, good 2 is protected less than good, 3 initially. The reduction in t_2 will lower protection to the less protected good, which may or may not improve welfare. In terms of Equation (10), the pollution term in the curly brackets counteracts the standard Meade term. Alternatively, if we distort the pollution charge less than t_2 ($\tau < t_2$ or $h < (1+t_2)\tilde{p}$), good 2 is protected more than good 3 and the pollution term reinforces the standard Meade term.

This result has a direct application to the NAFTA. To the extent that pollution standards are high in the United States and preferential liberalization happens to be in polluting, import-competing industries, at least in the absence of international factor flows, conventional gains from such liberalization may not accrue.

The partner-country problem

In the standard Meade model, the analysis of partner countries is symmetric in the sense that results derived for one country apply to the other country. This is not true in our model since results depend critically on whether the polluting industry is an import-competing or export industry. To see this, let us briefly consider country B's problem. We use upper-case letters to identify B's variables. The difference between A and B is that the latter exports good 2 and imports good 1, while the former does the opposite.

By analogy with (10), starting from $T_1 = T_3$, the effect of a change in T_1, the tariff on the good imported from partner country A, can be written

$$N\,\frac{dU}{dT_1} = \frac{1}{1+T_1}\,[-T_1M_{21} + M_{1H}\,\{H - (1+T_1)(M_Z - T_1M_{Z1} - T_3M_{Z3})\}]. \tag{11}$$

This equation is obtained by interchanging subscripts 1 and 2 and replacing lower-case letters by upper-case letters. This means that $N \equiv M_U - T_1M_{1U} - T_3M_{3U}$. At first, it may seem that the effect of preferential trading will be no different from that encountered for A. This is false, however. The key point is that the expected sign of $M_{H1} \equiv -R_{H1} \equiv \partial Z/\partial(1 + T_1)$ is negative; a rise in the price of good 1 leads to a contraction of other sectors including the polluting sector. A stringent pollution policy now reinforces the traditional Meade effect, while a lenient policy does the opposite. Specifically, if $H < (1 + T_1)(M_Z - T_1M_{Z1} - T_3M_{Z3})$, the second term is positive and preferential liberalization is not necessarily welfare-improving. Under the lenient policy, good 2 enjoys more effective protection than good 1 and preferential liberalization leads to its expansion which is harmful. This result has the implication that if we view Mexico's pollution standards too low and the country exports goods produced by polluting industries, preferential trading can very likely lower welfare in Mexico!

3. Incorporating optimal pollution policies

We saw in the previous section that the initial level of the pollution charge is critical to whether the introduction of preferential trading improves or worsens welfare. For a country importing the polluting good from the union partner, an excessively high pollution charge undermines the Meade result. For a country exporting the polluting good, an excessively low pollution charge undermines the Meade result.

We can ask the question: what happens if the pollution charge is set optimally? To answer, we must first derive the optimal pollution charge and then evaluate our comparative statics in Equation (10) at that level of h.

The first point to note is that the optimal pollution charge is not given by $h = \tilde{p}$. Given $t_2, t_3 > 0$, it does not make sense to leave the pollution charge undistorted. More subtly, even though setting $\tau = t_2 = t_3$ yields equal effective protection to the two imported goods and equal distortion in consumption, it is not the optimal level of h.

To understand why, consider for a moment the model when there is no pollution. Suppose we leave t_3 fixed and lower t_2 by an infinitesimally small amount. Assuming substitutability between good 2 and the exportable, we know that such a reduction at $t_2 = t_3$ is beneficial. In fact we know that, as we continue to lower t_2, welfare rises up to a point and then begins to decline. The level of tariff at which the welfare change switches sign is strictly positive and, following Lipsey (1958), is referred to as the second-best optimum tariff.

Let us now turn back to the issue of the optimum pollution charge given $t_2 = t_3 > 0$ in our model. If the pollution charge is set to yield $\tau = t_2 = t_3$, goods 2 and 3 will have equal effective protection. Under the usual substitutability assumption, we know that if we reduce protection to good 2 (or good 3), welfare will improve. Because we are now taking t_2 and t_3 fixed, this goal cannot be accomplished directly. But it can be accomplished indirectly by distorting h beyond $\tau = t_2$. This is exactly what our formal derivation below of Equation (15) yields.

Recall that the home country's equilibrium is given by Equations (4) and (5). To find the optimum h, let us first differentiate these equations and solve for du/dh. It is relatively straightforward to show that

$$\begin{aligned} n\frac{du}{dh} &= [h - (m_{\mathrm{z}} - t_2 m_{z2} - t_3 m_{z3})]m_{hh} + (t_2 m_{2h} + t_3 m_{3h}) \\ &= \tau\tilde{p}m_{hh} + (t_2 m_{2h} + t_3 m_{3h}) \end{aligned} \tag{12}$$

where the second equality is obtained by making use of the definitions in (8) and (9).

We first show that the right-hand side is positive at $\tau = t_2 = t_3$. Because m_h is homogeneous of degree zero in all prices, we have

$$m_{1h} + (1 + t_2)m_{2h} + (1 + t_3)m_{3h} + hm_{hh} = 0. \tag{13}$$

Substituting the value of m_{hh} from (13) into (12), taking account of $h = (1 + \tau)\tilde{p}$, we have

$$\begin{aligned} n\frac{du}{dh} &= -\frac{\tau}{1+\tau}[m_1h + (1 + t_2)m_{2h} + (1 + t_3)m_{3h}] \\ &= -\frac{1}{1+\tau}[\tau m_{1h} + (\tau - t_2)m_{2h} + (\tau - t_3)m_{3h}]. \end{aligned} \tag{14}$$

According to the last equality, the right-hand side is positive at $\tau = t_2 = t_3$ if $m_{1h} < 0$. Recalling that $m_{1h} = -r_{1h}$ and that good 1 does not pollute, we do obtain $m_{1h} < 0$. Normally, we expect substitutability which implies that the price cross-partials of the revenue function are negative. But given that pollution is an input, in the spirit of Lopez and Panagariya (1992), we necessarily obtain complementarity between the price of pollution and goods which do not pollute. The rise in h causes the polluting industry to shrink, pushing resources into non-polluting industries.

Thus, we see that the optimal distortion in the pollution price must exceed $t_2 = t_3$. To obtain the precise value of the optimal τ, set the right-hand side of Equation (14) equal to zero and solve for τ at $t_2 = t_3$. We have

$$\tau^* = \frac{t_2(m_{2h} + m_{3h})}{m_{1h} + m_{2h} + m_{3h}}. \tag{15}$$

Recalling that $m_{1h} < 0$, this equation immediately yields $\tau^* > t_2$.

Let us now turn to the effect of the introduction of preferential trading when the initial value of pollution charge is set at the optimum level. For this purpose, it is convenient to calculate

$$(1 + \tau)\tilde{p} - (1 + t_2)\tilde{p} = (\tau - t_2)\tilde{p} = \frac{-t_2 m_{1h}\tilde{p}}{m_{1h} + m_{2h} + m_{3h}}. \qquad (16)$$

Substituting from (16) into (11), we have

$$n\,\frac{du}{dt_2} = \frac{1}{1 + t_2}\left[- t_2 m_{21} - \frac{t_2 m_{1h} m_{2h}\tilde{p}}{m_{1h} + m_{2h} + m_{3h}}\right].$$

The first term inside the brackets is the usual Meade term and is negative. Since $m_{1h} < 0$, $m_{2h} > 0$ and the denominator of the second term is positive, the second term, inclusive of the negative sign, is positive. Therefore, for a reduction in t_2, the first term will contribute positively while the second term will contribute negatively to welfare. Thus, even though the pollution charge is set optimally, this does not guarantee that the welfare effect of the preferential trading arrangement is unambiguously positive.

4. Incorporating transnational pollution

Since pollution is only domestic in the above set-up, there is little scope for coordinating policies across countries.[5] In this section, we consider the case where pollution generated in one country spills over into the other. We return to our original set-up where pollution charges are not set optimally. Let $a(A)$ be the fraction of pollution that spills over from the foreign (home) country to the home (foreign) country. Total pollution incurred by home (foreign) consumers is therefore $z + aZ$ $(Z + Az)$. Since foreign pollution now enters into home utility, we have to consider the two countries jointly. Equilibrium is defined by

$$m(1, 1 + t_2, 1 + t_3, h; z + aZ, u) = t_2 m_2(\cdot) + t_3 m_3(\cdot) + h m_h(\cdot) \qquad (17)$$

$$m_h = z \qquad (18)$$

$$M(1 + T_1, 1, 1 + T_3, H; Z + Az, U) = T_1 M_1(\cdot) + T_3 M_3(\cdot) + H M_H(\cdot) \qquad (19)$$

$$M_H = Z \qquad (20)$$

where (17) and (19) are the home and foreign economies' respective budget constraints and (18) and (20) follow from the properties of the revenue and import functions as before.

We turn first to the home country and consider a change in t_2 with a fixed pollution charge h. Differentiating (17) and (18) yields

$$n\,du + (m_z - t_2 m_{2z} - t_3 m_{3z})(dz + a\,dZ) = (t_2 m_{22} + t_3 m_{32} + h m_{h2})dt_2 \qquad (21)$$

$$dz = m_{h2}dt_2 = -r_{h2}dt_2 \qquad (22)$$

where we have exploited the fact that $m_{hu} = m_{hz} = 0$ (because u and z enter only into $e(\cdot)$, while h enters only into $r(\cdot)$). Conducting a parallel exercise for the foreign country and differentiating (19) and (20) yields

---

[5] As noted above, however, there is scope for coordinating one's own trade and pollution policies.

$$\begin{aligned} N\,dU + (M_Z - T_1M_{Z1} - T_3M_{Z3})(dZ + a\,dz) \\ = (T_1M_{11} + T_3M_{31} + HM_{H1})\,dT_1 \end{aligned} \tag{23}$$

$$dZ = M_{H1}dT_1 = -R_{H1}dT_1. \tag{24}$$

Substituting (22) and (24) into (21) for dz and dZ, we obtain

$$\begin{aligned} n\,du = (t_2m_{22} + t_3m_{32} + hm_{h2})\,dt_2 + (m_z - t_2m_{2z} - t_3m_{3z})r_{h2}dt_2 \\ + (m_z - t_2m_{2z} - t_3m_{3z})\,aR_{H1}dT_1. \end{aligned}$$

Note that the above expression is analogous to (6) except for the last right-hand-side term. From the homogeneity of properties of $m(\cdot)$, the bracketed expression in the last term is positive. Since R_{H1} is positive, the entire last term is also positive: a reduction in foreign tariffs T_1 lowers home country welfare. Lowering T_1 expands the foreign polluting sector and the amount of transnational pollution incurred by home residents.

Similarly, the foreign-country problem yields

$$\begin{aligned} N\,dU = (T_1M_{11} + T_3M_{31} + HM_{H1})\,dT_1 + (M_Z - T_1M_{Z1} - T_3M_{Z3})R_{H1}dT_1 \\ - (M_Z - T_1M_{Z1} - T_3M_{z3})\,Ar_{h2}dt_2. \end{aligned}$$

Compared to our previous result, transnational pollution again yields an extra effect given by the last term on the right-hand side. Since $r_{h2} \leq 0$, this extra term is negative. Not surprisingly, we get an asymmetric result compared to the home country problem. Lowering t_2 raises foreign welfare by causing the home polluting sector to shrink and reducing the amount of cross-border pollution.

The above suggests the need for coordinating tariff reductions across countries as part of a preferential trading arrangement in the presence of transnational pollution. Induced changes in cross-border pollution and their impact on partner-country welfare should be internalized in the tariff reductions negotiated as part of the trading arrangement. In the above case, for example, this would imply that the home country reduce its tariffs by more and the foreign country by less than it would otherwise have done individually.

5. Conclusion

For expositional clarity, the paper relies upon a simple model of regional integration. Nonetheless, the model manages to shed light on several questions regarding regional integration and the environment. We return to the two analytical issues posed in the introduction.

What implications does the inclusion of environmental pollution have for the traditional analysis of the welfare economics of regional integration? As shown in sections 1 and 2, pollution affects the traditional welfare analysis of regional integration schemes in two ways. Through its role as an input into production, it may lead to pollution-induced trade diversion which counteracts the traditional Meade result. Through its second role as a 'good' which enters negatively into the utility function, it may lead to pollution-induced trade creation which reinforces the Meade result. The different trade effects induced by pollution highlight the importance of separating out the two analytical roles played by pollution in the context of regional integration.

What implications does the inclusion of environmental charges have for the traditional results on gains from preferential trading? As shown in sections 1 and 2, the level of the pollution charge is critical in determining whether the Meade result breaks down. The way in which the pollution charge enters, however, depends upon the country under analysis. In particular, the results hinge upon whether the polluting industry is import-competing or an export industry. If the polluting industry is an import-competing industry (the home country in our set-up), then an excessively stringent pollution policy works against the conventional gains from preferential liberalization. By contrast, if the polluting industry is an export industry, then preferential liberalization could reduce welfare under an excessively lax pollution policy.

Interestingly, as shown in section 3, setting pollution policies optimally does not by itself guarantee that there are positive welfare gains from preferential tariff liberalization due to induced trade diversion effects. This suggests the need for jointly coordinating tariff and pollution policies when making discriminatory tariff reductions.

While there is scope for coordinating one's own pollution and trade policies when pollution is domestically generated, the rationale for coordinating pollution policies across countries and including them in regional arrangements requires that pollution be transnational. In such a context, tariff reductions in one country affect the utility of residents in the other by affecting the amount of transnational pollution. Again, the results hinge upon whether the polluting industry is import-competing or not. As shown in section 4, when the polluting industry is import-competing (export), preferential liberalization by the partner country has an additional positive (negative) impact. Joint coordination of tariff reductions would allow the externalities from induced changes in cross-border pollution to be properly internalized when forming a preferential trading area.

References

Baumol, W.J. and W.E. Oates (1988), *The Theory of Environmental Policy*, Cambridge University Press.

Copeland, B.R. (1994), 'International trade and the environment: policy reforms in a polluted small open economy', *Journal of Environmental Economics and Management* **26**: 1–22.

Corden, M. (1976), 'Customs unions theory and the nonuniformity of tariffs', *Journal of International Economics* **6**: 99–106.

Dixit, A.K. and V.D. Norman (1980), *Theory of International Trade*, Cambridge University Press.

Lipsey, R. (1958), 'The theory of customs unions: a general equilibrium analysis', PhD thesis, University of London.

Lloyd, P.J. (1982), 'On the theory of piecemeal reform: the case of pure imported intermediate inputs', *American Economic Review* **82**: 615–625.

Lopez, R. (forthcoming), 'The environment as a factor of production: the effects of economic growth and trade liberalization', *Journal of Environmental Economics and Management*.

Lopez, R. and A. Panagariya (1992), '3 × 3 theory of customs unions', *Journal of International Economics* **12**: 41–63.

McMillan, J. and E. McCann (1981), ‘Welfare effects in customs union’, *Economic Journal* **91**: 697–703.

Meade, J.E. (1955), *The Theory of Customs Unions*, Amsterdam: North Holland.

Panagariya, A. (forthcoming), ‘The Meade model of preferential trading: history, analytics and policy implications’, *in* B.J. Cohen, ed., *International Trade and Finance: New Frontiers for Research: Essays in Honor of Peter B. Kenen*, New York: Cambridge University Press.

Panagariya, A., K. Palmer, W.E. Oates and A.J. Krupnick (1993), ‘Quality of the Environment Division’, Discussion Paper QE93-07, Resources for the Future, Washington, DC.