Trade Policy and Environmental Regulation in the Asia-Pacific: A Simulation

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1. INTRODUCTION

INTERNATIONAL trade and the environment has become one of the most controversial issues of globalisation raising concerns of industries' international competitiveness, accelerated environmental degradation, and a race to the bottom of environmental standards (e.g. Walley, 1996). From a trade-theory point of view these fears hinge upon the assumption that differences in environmental regulation are the only or predominant cause of comparative advantage and trade.[1] However, a review of the existing empirical work shows that the evidence is inconclusive (e.g. Dean, 1996; and Jaffe et al., 1995). For example, Tobey (1990) and Grossman and Krueger (1993) suggest that trade patterns are unaffected by environmental control costs, whereas Kolstad and Xing (1995) find that the laxity of environmental regulations in a host country is a significant determinant of foreign direct investment (FDI) from the US chemical industry.

The present paper puts this discussion in the context of trade liberalisation among APEC member countries. Looking at the region's initial economic and

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[1] For a discussion how environmental standards can be offset by factor abundance as another determinant of trade see Copeland and Taylor (1996). If the pollution-intensive good also happens to be capital intensive, then under free trade capital-abundant developed countries may specialise in and export the pollution-intensive good even if their industries have to comply with higher environmental standards.

policy conditions further trade liberalisation could spark as controversial a debate as the one on environmental costs and benefits prior to NAFTA (e.g. Emerson and Collinge, 1993). While APEC includes some of the most open and export-dependent developing countries in the world and the importance of international trade has increased during the 1990s (e.g. Lewis et al., 1995), living standards and the level of environmental regulations vary substantially across countries in the region.

By how much would the typical gains from further trade liberalisation within APEC have to be adjusted for environmental welfare losses due to increased pollution? If free trade promotes the shift of dirty industries to developing countries with relatively lax environmental standards, should this not result above all where the world's largest free trade area between developed and developing countries emerges? Would stricter environmental regulation in one region merely result in a 'crowding out' of pollution to other regions with laxer standards?

We use a computable general equilibrium (CGE) approach building on a typical static multi-country trade model and incorporating an environmental submodel based on Perroni and Wigle (1994) in order to analyse the environmental effects of trade liberalisation among the member countries of APEC.[2] In the model, environmental policy requires firms and consumers to abate a certain fraction of emissions. Abatement costs increase with the pollution intensity of sectors and with required abatement levels and thus affect relative prices and trade patterns, which in turn affect output and pollution.

Given the difficulty the empirical literature faces in measuring the key variables of the trade-environment nexus, namely a country's openness or trade regime (Leamer, 1988; Dollar, 1992; Edwards, 1992; and Harrison, 1996), and the stringency of environmental standards, this CGE-simulation approach may provide a more direct account of the effects of the interaction between trade liberalisation and environmental regulation.

Our major findings are that even drastic changes in trade policy would yield only small effects on pollution for APEC member countries. Furthermore, liberalised trade can reduce pollution in regions with relatively lax environmental standards, as the latter do not necessarily produce a comparative advantage in pollution-intensive industries. Moreover, even where production tends to specialise and trade patterns may shift towards pollution-intensive industries, consumption remains diversified and thus pollution from it has a stabilising effect on overall pollution levels. Finally, we show that trade policy is less effective than addressing environmental problems directly via stricter regulation.

[2] Two previous CGE studies have looked at the environmental impacts of trade liberalisation in the APEC region. However, both of them have a very specific country-focus. Beghin et al. (1995) look at a coordinated trade liberalisation and emissions reduction programme for Mexico, whereas Lee and Roland-Holst (1993) are concerned with pollution and bilateral trade between Indonesia and Japan.

Interestingly, a one-sided increase in environmental standards by the US-Canada region, while substantially reducing pollution there, has apparently no significant repercussions on pollution and welfare in other model regions.

The paper is organised as follows. Section 2 briefly explains the structure of the model and Section 3 deals with its implementation, including use of data and calibration. Section 4 discusses the results of a range of simulations encompassing trade liberalisation under various environmental policy regimes. Section 5 concludes.

2. MODEL STRUCTURE

a. Multi-country Trade Model

The multi-country trade model is within the typical lines of many CGE models.[3] On the production side, a constant-returns-to-scale technology (CRTS) is specified with fixed input coefficients for intermediate goods and value added.[4] The latter is a constant-elasticity-of-substitution aggregate of two primary factors, labour and capital. Both factors are assumed to move freely across industries. Their total supply, and thus employment, is fixed. The model therefore abstracts from international factor mobility and from any consumer demands for factors, notably a labour-leisure trade-off.

The demand system is modelled as a hierarchy of nested CES functions. There is only one type of final demand, consumption, which is first allocated to specific commodities. Then total demands by commodity are calculated, by adding final demand and intermediate demand, and split into demand for domestic goods and imports. The resulting composite import demand for each commodity is then distributed among the model's several regions, which give the imports by commodity from each of the model's regions. Hence the model is 'Armingtonised' in that each commodity is differentiated by country of origin and the elasticity of substitution is finite. This strategy is used to accommodate the widely observed phenomenon of intra-industry trade, which otherwise would be incompatible with the CRTS assumption on the production side of the model.

Note that the structure of the multi-country trade model is intentionally kept simple and thus close to the basic structure of most CGE trade models. This

[3] For an overview of the structure of applied general equilibrium models, including mathematical background and presentation of models in the GAMS (General Algebraic Modelling System) programming language, which is also used here, see Ginsburgh and Keyzer (1997).

[4] For a survey of supply and demand-side characteristics in CGE trade models see Shoven and Whalley (1984, pp. 1036 ff). Four out of six multi-country-trade models presented there make use of CES value-added functions plus fixed coefficients for intermediate inputs.

allows one to include the complexity of the environmental sub-model while limiting the amount of speculative element in the model as a whole.[5]

b. Environmental Sub-models

Perroni and Wigle (1994) make a first attempt at embedding an environmental sub-model into a multi-country framework, in order to assess the effects of trade liberalisation on the environment.[6] The main features of the model used here are borrowed from their approach. At the same time, while still in the confines of the Perroni and Wigle model, a more realistic approach to policy enforcement is taken here. This allows for a comparison of trade liberalisation effects under three different environmental policy scenarios, which will be outlined in further detail below.

The major assumptions implemented here are as follows: There is only one type of pollutant, which results from both production and consumption. Pollution is strictly local and only affects the environmental quality in the country or region where it originates.[7] The model is static, which implies that pollution has no stock feedback effects, and does not accumulate.[8] It thus lends itself rather to environmental damage from low level emissions (including those of nitrous oxide, sulphur dioxide, pesticides and fertilisers) as opposed to irreversible environmental damage such as biodiversity decline or ozone depletion. To the

[5] For example, Harris (1984) notes with respect to more elaborate multilateral trade models that would allow for imperfect competition, that the results are generally more parameter-sensitive than in the competitive models, in particular as regards scale elasticities, the degree of collusive pricing, or basic import and export elasticities.

[6] Starting with Leontief (1970) most environmental CGE models have been single-country approaches aiming at assessing the effects of a change in environmental policy. For example, Bergman (1991) simulates the effects on factor prices and resource allocation of a policy requirement to reduce atmospheric emissions for the Swedish economy. Hazilla and Kopp (1990) attempt to estimate the social costs of environmental quality regulations mandated by the Clean Air and Clean Water Acts in the United States. In addition to policy changes, Dufournaud et al. (1988) look at the net effects of technological improvements on pollution in a single country model.

[7] Limiting the analysis in the basic model to local effects of pollution can be justified as follows. To start with, regulation of transboundary pollution is not well developed, not to mention that its enforcement in most cases still is only debated in theory (e.g. greenhouse gas emissions related to global warming). Therefore it does not appear to be an aspect of environmental regulation that differs across countries. The simulations in this paper, however, primarily aim to look at the interplay of differences in regulation and freer trade. Apart from this, data pertaining to global pollution and its effects is even more scarce than on local pollution.

[8] Using a classification from Tietenberg (1996) this assumption may be accurate for *fund pollutants*: This type of pollutant degrades or breaks down within a short period of time. Therefore, if the degradation rate is higher than the rate of injection, fund pollutants only have a current-period effect on environmental quality and do not accumulate. Typical examples for this type of pollutant are thermal water pollution or organic residuals that degrade and break down over time. On the other hand, pollution may accumulate in the case of *stock pollutants*, which cannot be removed or transformed by any natural process. Main examples are inorganic chemicals and minerals.

extent that the regenerative capacity of the environment cannot absorb pollutants or that pollution accumulates, the model will under-estimate the welfare costs of emissions, especially in the long run. But as long as this bias occurs as well when the benchmark equilibrium is computed, the simulation exercise may nevertheless be useful to assess the changes in pollution and welfare induced by trade policy.

It is assumed further that environmental policy requires firms and consumers to abate a certain fraction of emissions they cause. In a command-and-control scenario this abatement level is fixed. Under a pollution tax, however, the agents will choose an optimal abatement level at which the marginal cost of abatement equals the marginal benefit from saving pollution charges.[9] This assumption requires one to specify an abatement cost function. As in Perroni and Wigle (1994), it is assumed that abatement costs per unit of emissions are independent of production and consumption levels, but they increase with the proportion of emissions abated.[10] Therefore, this proportion is the same across all sectors for a given country with given environmental standards (and emission charges). However, abatement costs per unit of output or consumption differ because of differences in pollution intensity (i.e. units of emission per unit of output), with environmental standards thus affecting relative prices and trade. (A complete documentation including notation of parameters, variables, and model equations is available from the author upon request.)

In order to assess the welfare effects of pollution, the environmental damage has to be evaluated. Total pollution, which is the sum of net of abatement emissions by all sectors, enters a convex environmental-damage function with a constant elasticity of damage with respect to pollution. The function's parameters may vary across countries to reflect differences in assimilative capacity. The resulting environmental quality is equal to the difference between endowments and damage. Environmental quality and per capita aggregate consumption then enter a Cobb-Douglas utility function to assess overall welfare. From this one gets a social valuation of environmental quality and thus social cost of emissions. Note that the share parameter of environmental quality in this function is assumed to be the same across all countries; preferences are identical and homothetic. Therefore, the social valuation of environmental quality cannot differ merely because of preferences. Differences across countries are due to differing environmental damage parameters or per capita incomes.[11] Finally, the internalisation rate of environmental externalities, also assumed to be the same

[9] Note that the production function with fixed input coefficients for intermediate goods rules out technological changes in favour of cleaner inputs as a response to stricter environmental standards.

[10] This approach has some empirical underpinning by Maloney and Yandle (1984, p. 240). The elasticity estimates for the cost functions also stem from them.

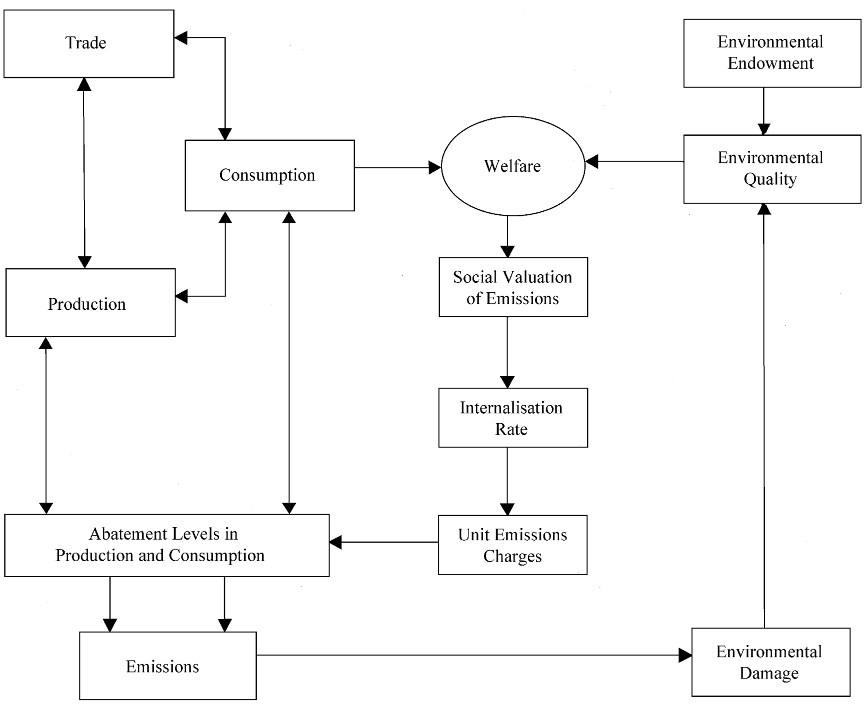
[11] For example, higher per capita income (or real consumption) yields a higher willingness to pay for a clean environment, which is equivalent to a higher valuation of environmental quality and in turn a higher social cost of emissions.

across all countries, determines the fraction of social emission costs which consumers and producers are forced to pay as emission charges. This determines the abatement levels chosen in production and consumption.

Note that if the internalisation rate is 100 per cent, the social cost of emissions equals the emission charge applied to consumers and producers per unit of emissions and thus all environmental externalities stemming from consumption and production are internalised. The internalisation rate therefore reflects the degree to which environmental policy makers enforce the social optimum. By equalising this rate across regions we assume that governments do not differ in the degree of their commitment to the social optimum. The mechanics of the environmental sub-model are illustrated in Figure 1.

In Perroni and Wigle (1994) there is a built-in policy-adjustment mechanism which results in tougher regulation (higher pollution taxes) and thus increased abatement efforts as per capita income increases or pollution levels go up. At the same time they find that the effect of trade liberalisation on pollution and welfare is very small. Can this be due to their assumption of an instantaneous policy response? To address this question and also permit a comparison with more realistic policy scenarios three different environmental regimes are analysed here:

FIGURE 1
Environmental Sub-model and Multi-country Trade Model



1. *Command-and-control* – the abatement levels in production and consumption are calibrated before the trade simulation and fixed thereafter.
2. *Fixed pollution tax* – firms and consumers face a fixed pollution tax which is calibrated before the trade simulation and fixed thereafter.
3. *Flexible pollution tax* – the pollution tax adjusts instantaneously to changes in environmental quality valuation, but the pollution tax is not socially optimal (i.e., internalisation rate is smaller than 100 per cent).

Finally, we also examine the effects of stricter environmental regulation under a given trade policy regime: *improved internalisation* – the pollution tax adjusts instantaneously and is set closer to a socially optimal level.

c. Closure

The model is closed by the assumption of balanced trade for all model regions which is implied by the macroeconomic assumption that income equals expenditure. In addition to this, all final demand is considered to be consumption. Hence the model abstracts from any impacts of trade liberalisation on domestic and foreign direct investment activities. Although these may be potent channels for relocating pollution-intensive industries to less-regulated countries and hence shifts in international pollution patterns, their sensitivity to trade liberalisation is often modelled ad hoc. Therefore, in order to limit the amount of speculation in the model, they are ignored here.[12]

3. IMPLEMENTATION

a. Data

Data on production, demand and trade is obtained from the Global Trade Analysis Project (GTAP) data base, Version 3 (1992 as reference year). The data base's main advantage is that it creates consistent bilateral trade, transport and protection data and combines it with individual country input-output data. It thus covers the important international and national economic linkages which are necessary to model the effects of changes in trade policy.[13]

[12] As Dewatripont and Michel (1987) point out, there is no clear-cut theoretical justification for the choice of a particular closure. Note that the simple rule chosen here makes the model both economically *and* ecologically static.
[13] For an introduction to and analysis of the GTAP framework, especially the procedures to create consistent bilateral trade flows, see Hertel (1996).

The 30 GTAP regions are aggregated into seven model regions (UCAN, ANZ, JAP, NIC4, SEA4, CHINA, ROW),[14] thus combining countries which are assumed to be at a similar stage of their economic development and therefore to apply similarly stringent environmental regulation.

There are nine economic sectors in the model, which are classified as representing 'dirty' (CHEM: industrial chemicals, IRON: iron and steel, NFM: non-ferrous metals), 'somewhat dirty' (PAWD: paper and wood products, RES: resources, TEX: textiles and leather products, OMFG: other manufacturing), and 'relatively clean' (FOOD: food, SER: services) industries, based on the ISIC- and SIC-code rankings for toxic release (Lucas et al., 1992) and pollution abatement and control expenditure (Low, 1992).[15]

Bilateral tariff protection rates which include tariff and non-tariff barriers are also obtained from the GTAP data base. In general, the textiles and food sectors are highly protected by all regions. As for the pollution-intensive industries, chemical products are significantly protected by many regions.

The two main data sources for the environmental sub-model are Low (1992) on estimates of industrial pollution and abatement cost functions, and the World Resource Institute (several issues) on environmental damage functions (see Perroni and Wigle, 1994). Most of the environmental parameters, however, stem from the calibration of the environmental sub-model and thus are subject to initial calibration conditions or assumptions.

b. Calibration

As for the multilateral trade model, calibrated values for most parameters, such as import shares by source country, commodity shares in consumption, or input-output coefficients, are based on GTAP data and obtained by computing the model backwards.[16] Elasticity coefficients for production (elasticity of

[14] UCAN: US and Canada; ANZ: Australia and New Zealand; JAP: Japan; NIC4: South Korea, Taiwan, Hong Kong and Singapore; SEA4: Thailand, Malaysia, Indonesia and Philippines; CHINA: China; ROW: Rest of the world.

[15] It may be argued that heavy use of fertilisers and pesticides makes agriculture and food production a pollution-intensive industry although the pollution abatement and control expenditure of this sector (Low, 1992) is very low. How changes in dirtiness coefficients will affect the simulation results will be subject to robustness tests further below. Also note that the model can capture the indirect pollution effects of seemingly clean sectors through input linkages to dirty industries. Apart from FOOD requiring CHEM this is important for SER which includes the GTAP sectors 'energy supply' or 'land, water and air transport' and thus has linkages to RES.

[16] Note that the GTAP data cannot be exactly reproduced in the benchmark equilibrium, because the actual trade, consumption and production data violate the closure rule of the model. However, when initial values for variables are recalibrated in the benchmark equilibrium the model produces realistic values for trade, production, and consumption. These comply with the closure rule of balanced trade or that income equals expenditure for all model regions. Refer also to Devarajan et al. (1994, p. 36, Ch. 3).

substitution between capital and labour) and demand (elasticity of substitution between goods, elasticity of substitution between imports and domestic goods, and elasticity of substitution between imports of different source countries) are obtained from Petri (1997) and reflect a consensus among modellers.

When calibrating the environmental sub-model, computation of benchmark emission charges and abatement levels would require previous knowledge of environmental quality and its social valuation which in turn depend on abatement levels. Therefore a simultaneous calibration procedure is necessary. Based on available abatement cost data for the US and an assumed internalisation rate of 33 per cent the first round of calibrations yields environmental parameters for the UCAN region. Assuming that the obtained share parameter of environmental quality in the social utility function is representative for all regions (no differences in environmental preferences) and abatement technologies are the same, then this gives the benchmark parameters and variables for all other regions in the second round of calibrations.

The environmental calibration results are summarised in Table 1. They also yield the abatement levels at which the command-and-control scenario is performed in Section 4. The benchmark emission charges and abatement levels appear to be plausible relative to the US values. In a survey of environmental standards for air pollution and their enforcement in East Asia, O'Connor (1994, p. 93) observes: (i) Japan has the strictest standards, in some cases even stricter than those of the United States; (ii) South Korea's and Taiwan's standards tend to be somewhat less strict; (iii) Indonesian standards are considerably more lax than US standards; (iv) With the exception of Japan, monitoring and enforcement have generally been weak. Further evidence for the lack of enforcement in Indonesia is provided by Hadad (1996), whose estimates for seven pollution-intensive industries show that they exceed the permissible pollution standards by 134 per cent to 7,500 per cent.[17]

Note that the model constrains environmental problems to a very high level of aggregation, that is to say there is only *one* type of pollution affecting only *one* type of environment under *one* type of policy regime that is the same for an entire model region. On the other hand, it seems desirable to have a breakdown into several pollutants, to account for the different dimensions of the environmental problem (e.g., water, land, and air), and to accommodate different environmental standards within a country or model region.[18] This would not only require parametrising damage functions for every pollutant, but it would also call for a breakdown of abatement functions according to pollutants. Moreover, the

[17] See Hadad (1996, p. 243).

[18] For example, Afsah et al. (1996) show that effective pollution levies in China are much higher in urbanised and/or industrialised provinces than elsewhere. The former, however, are likely to be the regions where the bulk of tradable goods are produced. Therefore, international trade flows may not be determined by national environmental standards but by local regulation instead.

TABLE 1
Benchmark Emission Charges and Abatement Levels

Region	*Social Valuation (Cost) of Emissions*	*Emission Charge (Internalisation Rate = 33%)*	*Abatement Level in Production (in %)*
UCAN	1.000	0.333	50.0
ANZ	1.063	0.354	60.0
JAP	1.077	0.359	62.7
NIC4	0.373	0.124	2.5
SEA4	0.319	0.106	1.6
CHINA	0.297	0.099	1.3
ROW	0.419	0.140	3.6

Note:
UCAN social valuation (cost) of emissions normalised to be 1.

question arises how to aggregate different kinds of pollution into a social damage function. Consequently, there would be huge informational requirements.[19]

These informational constraints notwithstanding, the framework offers a consistent approach to estimating the welfare effects of pollution, and the structure chosen lends itself to comparing the effects of trade policy on pollution and welfare with those of domestic environmental policy instruments (e.g., increase of pollution tax to a socially optimal level) as shown below.

4. SIMULATION

a. Environmental Regulation Based on Command-and-control

The environmental policy regime chosen for the simulations in this section is fixed command-and-control abatement levels. This may be considered the most realistic scenario. As O'Connor (1994) shows, the command-and-control approach to environmental management is predominant not only in the countries of his survey (Japan, South Korea, Taiwan, Thailand and Indonesia) but in virtually all countries with an environmental management system. Furthermore, the most commonly used regulation in the case of industrial pollution takes the form of discharge standards, which imply a minimum fraction of pollution to be abated.[20]

The focus in this section is on two different trade-policy simulations. The first represents a 50 per cent reduction or complete elimination of tariff and non-tariff

[19] Interestingly, Lee and Roland-Holst (1993) break down pollution into twelve different types of emissions, but keep the pollution coefficients of economic activities fixed across countries. Therefore, they must abstract from two key environmental policy features of the model presented here: trade induced regulatory changes and regulatory differences across countries.

[20] Even though specific abatement levels may not be the most efficient environmental regulation, it appears that the rationale for their use has been the relative certainty of their effectiveness.

trade barriers between the APEC member regions (but excluding ROW) on the three most pollution-intensive goods (CHEM, IRON, NFM). The second is a 50 per cent or 100 per cent reduction of trade barriers between the same set of regions on all goods. The rationale for focusing first on pollution-intensive goods is as follows: (i) Trade-induced changes in production patterns of these goods have the largest direct impact on pollution; (ii) Production-cost differences due to differences in environmental regulation are most significant for these goods, which is why some industrial lobbyists have called for trade restrictions to protect these industries in tightly regulated countries.

The effects on pollution and welfare are given in Table 2, and they appear to be fairly modest. Even when all tariffs and non-tariff barriers are eliminated resulting changes in pollution remain below 2 per cent in most of the regions. The effects on welfare remain below 1 per cent for all but one region and are even below 0.5 per cent in many regions.[21] Note that liberalisation does not necessarily lead to welfare gains in these scenarios. This is because of adverse effects stemming not only from pollution (negative externality) but also from changes in the terms-of-trade, given the large size of the regions, and from trade diversion and other second best problems, arising in particular when trade is partially liberalised.

Interestingly, there is no specific pattern that distinguishes countries with high abatement levels from those with low ones. Even in some developing areas, trade liberalisation results in a small reduction of pollution levels.

Table 3 illustrates the effects on welfare and pollution when trade barriers on all goods are reduced among APEC regions. Compared to the previous partial trade-policy changes, the effects are somewhat magnified. However, the overall changes in emissions and welfare remain fairly limited even for the most radical trade policy scenarios, so that the conclusions drawn above remain valid.

The results also suggest that the effects are dampened by the relative stability of pollution from consumption. Changes in pollution from consumption are negligible in the above scenarios and they tend to be smaller than changes on the production side throughout all of the following simulations. Trade may induce specialisation in production, but consumption is likely to remain much more diversified. Therefore, diversified consumption has a stabilising effect on pollution levels. Whereas this is often overlooked in the trade-and-environment debate, the model helps to emphasise the role of consumption in explaining the limited effects of trade on the environment.

While the conclusions above pertain to the overall economy level, trade liberalisation tends to have stronger effects on the output levels of and thus

[21] The numbers are relative changes in the representative agents' utility index. Since the model is based on linear homogeneous utility functions, these percentage changes can be easily interpreted as compensating variation (when multiplied with the *ex-post* income levels) and equivalent variation (when multiplied with the *ex-ante* income levels). See Shoven and Whalley (1984, p. 1014).

TABLE 2

Welfare and Pollution Effects (in per cent with respect to benchmark) of Partial Trade Liberalisation (command-and-control)

Reduction of Trade Barriers	*50 Per Cent*				*100 Per Cent*			
	Emissions			*Welfare*	*Emissions*			*Welfare*
	Total	*Production*	*Consumption*		*Total*	*Production*	*Consumption*	
UCAN	0.00	0.00	0.00	−0.01	0.00	0.00	0.00	−0.04
ANZ	0.00	0.00	0.00	−0.05	0.00	0.00	0.00	−0.13
JAP	0.24	0.28	0.00	0.01	0.47	0.55	0.00	0.03
NIC4	0.32	0.36	0.00	−0.12	0.97	0.73	0.00	−0.27
SEA4	−0.79	−0.93	0.00	−0.30	−1.57	−1.85	0.00	−0.78
CHINA	−0.69	−1.63	0.00	−0.43	−2.08	−2.44	0.00	−1.14
ROW	−0.10	−0.09	0.17	0.08	−0.17	−0.20	0.17	0.18

TABLE 3
Welfare and Pollution Effects (in per cent with respect to benchmark) of Complete Trade Liberalisation (command-and-control)

Reduction of Trade Barriers	*50 Per Cent*				*100 Per Cent*			
	Emissions			*Welfare*	*Emissions*			*Welfare*
	Total	*Production*	*Consumption*		*Total*	*Production*	*Consumption*	
UCAN	−0.22	−0.26	0.00	−0.04	−0.87	−1.04	0.00	−0.18
ANZ	−2.50	−2.94	0.00	−0.04	−7.50	−8.82	0.00	−0.17
JAP	0.94	1.10	0.00	0.36	4.47	5.23	0.00	−0.34
NIC4	1.95	1.82	0.00	0.19	7.14	8.00	−2.94	−1.81
SEA4	0.79	0.93	0.00	−0.97	6.30	7.41	−5.00	−5.00
CHINA	−2.08	−2.44	0.00	−1.28	−6.25	−6.50	−4.76	−5.41
ROW	−0.34	−0.49	0.68	0.95	−1.37	−2.06	2.87	3.79

TABLE 4
Percentage Change in Real Output Due to Complete Trade Liberalisation (command-and-control)

	Chemicals		*Iron and Steel*		*Non-ferrous Metals*	
Reduction of Trade Barriers	*50%*	*100%*	*50%*	*100%*	*50%*	*100%*
UCAN	−0.52	−2.58	−2.44	−8.70	−1.75	−6.56
ANZ	−5.50	−18.00	−12.28	−40.35	−8.93	−30.36
JAP	1.87	8.31	6.09	22.71	7.16	27.90
NIC4	4.88	16.85	1.86	10.52	1.05	12.63
SEA4	−0.39	9.73	−4.55	0.00	5.88	41.18
CHINA	−4.53	−10.74	−3.70	−10.37	−7.41	−14.81
ROW	−0.91	−3.33	−1.63	−6.42	−1.78	−7.38

pollution levels due to individual sectors. Table 4 summarises the changes in real output for the three most polluting industries which also have the highest abatement cost. Nevertheless, a change in production patterns reflects primarily the change in protection levels rather than abatement cost differentials relative to main trading partners. For example, although they face the lowest abatement costs, China's pollution intensive sectors contract when they are no longer protected by the highest tariff and non-tariff barriers in the region. In the same vein, given that the expansion and contraction of pollution-intensive industries occurs simultaneously in regions with similar standards (e.g. JAP vs. ANZ), these standards hardly seem to affect trade patterns.

This dominance of protection levels is due to the fact that abatement cost tends to be much smaller relative to production cost than the cost equivalent of trade barriers. For example, for the dirty industries abatement costs in highly regulated regions range at a maximum between 1 and 2.5 per cent of production cost while the cost equivalent of China's trade barriers ranges between 8 and 33 per cent.

b. Environmental Regulation Based on Fixed Pollution Tax

When environmental regulation is imposed by fixed emission charges, producers and consumers respond by choosing an optimal abatement level at which the marginal cost of abatement equals the emissions charge. While the fixed-emission-charge scenario tends to produce somewhat stronger effects on pollution and welfare than the command-and-control scenario, again, most of the effects of liberalising trade appear to be small.[22] Also, lax environmental regulation in developing areas does not necessarily imply an increase in their

[22] Only for tightly regulated Japan does pollution drop substantially when trade barriers are completely eliminated within APEC. This variation stems mostly from changes in abatement levels as agents adjust these optimally to the fixed emissions charge. Japan's abatement costs drop, however, because of a decline in factor prices. On the other hand, abatement levels remain stable in the developing regions of APEC, so that pollution increases must have been caused by shifts towards more pollution-intensive production and/or (to a lesser degree) consumption.

pollution once trade is liberalised. Moreover, resulting changes in pollution from consumption tend to be much smaller than those caused on the production side.

c. Environmental Regulation Based on Flexible Pollution Tax

In this section environmental regulation instantaneously adjusts to changes in income, environmental quality and pollution. However, the internalisation rate is kept at 33 per cent, which means that the emissions charges imposed are only 33 per cent of the socially optimal charge.

Compared to the previous section, the effects of trade liberalisation on pollution and welfare tend to be smaller under this environmental policy scenario. This is because any first-round increases in pollution yield higher emission charges – environmental quality becomes relatively more scarce and thus its social value increases – which in turn result in higher abatement levels chosen by firms and consumers, offsetting the first-round increases in pollution. Thus the policy regime has a stabilising effect on pollution levels. This helps to explain why Perroni and Wigle (1994) find only modest effects of trade policies on environmental quality, because their analysis deals exclusively with the environmental-policy scenario of this section. Note, however, that such a policy regime is unlikely to exist in the real world, especially in the short run. Environmental policy tends to respond only with a considerable delay to changes in pollution or, more generally, in social valuation of environmental quality.[23]

d. Improved Internalisation

All previous scenarios suggest that trade policy is not an effective tool to mitigate environmental problems. This becomes even more obvious when it is compared to changes in environmental policy. Table 5 summarises the results of an increase in the internalisation rate, first to 40 per cent, then to 50 per cent in all regions of the model.

First, it is obvious that such a policy measure, which reduces the gap between social and private cost of pollution without distorting other parts of the economy, can only increase economic welfare (if enforcement cost is ignored). Second, the results show that even a relatively modest tightening of environmental regulation – the internalisation rate increases first from 33 per cent to 40 per cent – causes more reduction in pollution than any dramatic or even radical change in trade barriers. This reduction is achieved mainly through an increase in abatement

[23] Jeong and Lee (1996) provide evidence in the case of South Korea for this. Their overview of the stages of the green movement in Korea clearly shows, that although awareness for worsening pollution dates back as far as the early 1960s, impacts on legislation became noticeable in the late 1970s only.

TABLE 5
Effects of Increased Internalisation Rate (in per cent with respect to benchmark)

Internalisation Rate	*40 Per Cent*			*50 Per Cent*		
	Pollution	*Abatement*	*Welfare*	*Pollution*	*Abatement*	*Welfare*
UCAN	−26.58	18.54	0.20	−58.42	40.82	0.38
ANZ	−36.67	16.00	0.23	−80.00	34.29	0.43
JAP	−31.72	9.82	0.17	−63.06	19.50	0.29
NIC4	−3.74	51.52	0.04	−9.86	133.33	0.10
SEA4	−3.23	69.05	0.00	−8.87	200.00	0.04
CHINA	−2.11	75.00	0.00	−5.63	229.17	0.00
ROW	−4.40	61.54	0.06	−12.00	170.77	0.12

levels, rather than a decline in production, resulting from the rise in the private cost of emissions.[24]

However, a uniform increase in environmental standards across all regions appears unlikely. Therefore, in another simulation, the effects of a unilateral toughening of environmental standards in the UCAN region are analysed. The impact on the environment in the UCAN region turns out to be essentially the same as shown in Table 5. However, in spite of its role as the largest trading partner within APEC, stronger US-Canada environmental standards, do not cause a crowding-out of pollution to other regions (i.e., all measurable effects on pollution and welfare remain below 0.01 per cent with respect to the benchmark equilibrium). This holds true for the current trade regime as well as under free trade. The result is primarily due to the fact that, as indicated in Table 6, a unilateral increase in environmental standards has only very small effects on output levels in the most affected industries. Therefore, higher standards result in increased abatement efforts (as reflected in the decline of pollution levels) but little or nearly no crowding out of pollution intensive industries. This is consistent with the finding in Section 4*a* that trade patterns mostly respond to changes in trade barriers rather than differences in environmental standards as the latter tend to have much weaker cost and price implications than the former. Note that

TABLE 6
Percentage Change (with respect to benchmark) in Real Output in UCAN

Internalisation Rate Increased to	*40 Per Cent*	*50 Per Cent*
CHEM	−0.14	−0.31
IRON	−0.12	−0.35
NFM	−0.15	−0.44

[24] Notice too, that the effect on pollution and welfare is more pronounced in the developed world, primarily because the benchmark emissions per unit of output are lower thus magnifying any further decline in emissions.

abatement cost not only represents a small fraction of production cost, but that the empirical estimate used for the elasticity of abatement cost with respect to abatement (Maloney and Yandle, 1984) yields a relatively flat marginal abatement cost function.[25] Combined with the results from partial trade-policy changes the results furthermore indicate that a unilateral increase in environmental standards targeting only one or two economic sectors is even less problematic in terms of crowding out.

e. Summary of Results

The simulations have produced four main results. First, under the most realistic scenario of command-and-control environmental regulation, even dramatic changes in trade policy have only small effects on pollution. Second, liberalising trade can reduce pollution in developing areas with relatively lax environmental standards primarily because previously highly protected pollution-intensive industries shrink. Low environmental standards do not appear to give rise, on average, to comparative advantage in pollution-intensive industries. Third, pollution from consumption has a stabilising effect on overall pollution levels. Fourth, stricter environmental regulation is more effective in addressing domestic pollution. This holds true for multilateral and unilateral policies. In the latter case, a unilateral increase in environmental standards by the US-Canada region has apparently no significant repercussions on pollution and welfare in other model regions, regardless of their degree of openness.

5. CONCLUDING REMARKS

This paper makes a first step towards simulating the impacts of trade liberalisation among APEC countries on pollution, environmental quality and welfare. Given that the APEC countries have experienced rapid economic integration, while their environmental standards continue to differ substantially, the effects of international trade on the environment are expected to be more pronounced than in any other region of the world. It appears, however, that even drastic changes in trade policy in the Asia-Pacific do not contribute to environmental problems or to their solution. Relative stability in pollution stemming from consumption further mitigates the potential effects of free trade via some possible relocation of pollution-intensive industries. Moreover, lax environmental regulations in some of the member countries do not necessarily

[25] Furthermore, this result is also due to the Armingtonisation of the model and the assumed immobility of capital and labour, which stabilise the cross border pattern of trade and production in the face of policy induced changes in production costs.

mean higher levels of pollution once the APEC countries can trade more freely with one another. From a policy perspective, the results suggest that trade barriers are both less effective and less efficient than domestic environmental regulation in controlling environmental problems.

Clearly the model presented here is only a very crude representation of the real world, in particular with respect to its static nature and the environmental mechanisms. Future research to improve it may take, but of course should not be limited to, the following directions. First, an improved understanding of the dynamics of pollution and environmental quality will help to more accurately assess the long run impacts of trade on the environment. Second, it is noteworthy that both environmental policies and trade induce technological changes including improved abatement or the substitution of polluting inputs for cleaner inputs. Especially by abstracting from imperfect competition and scale economies related to the implementation of clean technologies the model leads to an underestimation of the effects of environmental policy and trade liberalisation on the use of cleaner technologies and thus pollution.[26]

Third, the model's assumption that all pollution is local appears to be heroic. If transboundary or global pollution is added to the picture, at least three questions have to be addressed: (i) How should global pollution be modelled, as a substitute or complement between local emissions?[27] (ii) How should its effects on national welfare be distributed, given that social costs of pollution differ substantially across countries? (iii) And how can the extent of asymmetry of transboundary pollution flows among model regions be quantified?

APPENDIX

Robustness Tests (for command-and-control policy scenario)

This appendix explores the robustness of the results presented above. There are two groups of tests to assess how sensitive the results are with respect to chosen parameter values. The first concerns the environmental sub-model. Lowering the initial internalisation rate of the benchmark model to 20 per cent increases the calibrated gross-of-abatement emissions of each sector by 60 per cent. Thus, by making all industries more pollution-intensive, it can be determined if the very limited effects of trade on environmental quality and pollution, for example via a change in the composition of output, arise from assigning gross-of-abatement

[26] For recent empirical evidence in this vein see Antweiler et al. (1998).

[27] A case in point is the role of transportation as a source of global emissions. On the one hand higher trade volumes may lead to increased demand for transportation thus causing more (transboundary) pollution, but on the other hand this inter-regional trade may replace intra-regional trade and transportation thus offsetting some first-round pollution increases.

TABLE A1
Welfare and Pollution Effects (in per cent with respect to benchmark) of Complete Trade-policy Changes (internalisation rate: 20%)

Reduction of Trade Barriers	*50 Per Cent*				*100 Per Cent*			
	Emissions			*Welfare*	*Emissions*			*Welfare*
	Total	*Production*	*Consumption*		*Total*	*Production*	*Consumption*	
UCAN	−0.20	−0.32	0.00	−0.04	−0.85	−1.03	0.00	−0.17
ANZ	−1.54	−3.57	0.00	−0.02	−7.69	−8.93	0.00	−0.09
JAP	1.00	1.17	0.00	0.34	4.42	5.35	−0.97	−0.38
NIC4	1.57	1.99	1.82	0.15	7.07	8.39	0.00	−1.90
SEA4	0.95	1.69	−3.03	−0.96	5.71	7.91	−6.06	−4.95
CHINA	−2.11	−1.98	−2.86	−1.17	−5.91	−5.45	−5.71	−5.26
ROW	−0.33	−0.50	0.72	0.92	−1.37	−2.07	2.76	3.73

Note:
Results of robustness tests for other environmental policy regimes are similar but not shown here because of space restrictions.

TABLE A2
Welfare and Pollution Effects (in per cent with respect to benchmark) of Complete Trade-policy Changes (low trade elasticities)

Reduction of Trade Barriers	*50 Per Cent*				*100 Per Cent*			
	Emissions			*Welfare*	*Emissions*			*Welfare*
	Total	*Production*	*Consumption*		*Total*	*Production*	*Consumption*	
UCAN	−0.22	−0.13	0.00	−0.07	−0.54	−0.52	0.00	−0.21
ANZ	−2.50	−2.94	0.00	−0.12	−5.00	−5.88	0.00	−0.29
JAP	0.71	0.83	0.00	0.18	3.29	3.86	0.00	−0.46
NIC4	1.30	1.45	0.00	−0.14	5.19	5.82	−2.94	−1.96
SEA4	0.79	1.87	−5.00	−1.30	4.72	6.54	−5.00	−5.07
CHINA	−1.39	−1.63	0.00	−1.56	−3.47	−3.25	−4.76	−5.41
ROW	−0.29	−0.46	0.68	0.85	−1.05	−1.63	2.20	3.00

Note:
Results of robustness tests for other environmental policy regimes are similar but not shown here because of space restrictions.

TABLE A3
Welfare and Pollution Effects (in per cent with respect to benchmark) of Complete Trade-policy Changes (high trade elasticities)

Reduction of Trade Barriers	*50 Per Cent*				*100 Per Cent*			
	Emissions			*Welfare*	*Emissions*			*Welfare*
	Total	*Production*	*Consumption*		*Total*	*Production*	*Consumption*	
UCAN	−0.32	−0.39	0.00	−0.01	−1.30	−1.57	0.00	−0.15
ANZ	−5.00	−2.94	0.00	0.03	−10.00	−11.76	0.00	−0.05
JAP	1.18	1.66	1.61	0.56	5.88	7.18	0.00	−0.20
NIC4	2.27	2.18	0.00	0.55	9.42	10.55	−2.94	−1.64
SEA4	1.57	0.93	0.00	−0.60	8.66	10.19	−5.00	−4.85
CHINA	−2.78	−3.25	0.00	−0.71	−8.33	−8.94	−4.76	−5.13
ROW	−0.37	−0.57	0.84	1.04	−1.72	−2.61	3.55	4.75

Note:
Results of robustness tests for other environmental policy regimes are similar but not shown here because of space restrictions.

emission coefficients that are too low. The findings in Table A1 indicate that making all industries significantly more pollution-intensive does not change the results presented in the previous section. The net effects of trade on the environment remain very limited.[28]

The second group of tests concerns the multilateral trade model. How sensitive are the results to the chosen trade elasticities? As shown in Table A2, lower import elasticities, i.e. reduced by 20 per cent, considerably reduce the effect of trade policy changes on the composition of domestic demand, output, and thus pollution. Depending on the environmental-policy scenario, and the kind of trade-policy changes, the effects disappear almost entirely. On the other hand, higher import elasticities, i.e. increased by 20 per cent, magnify the effects of trade policy on emissions and welfare (see Table A3), but they remain modest, and changes in emissions and welfare levels clearly remain below 10 per cent or 5 per cent respectively for most countries, regardless of the environmental policy regime.

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[28] It may be argued that the pollution intensity is under-estimated only for a few sectors in the benchmark calibration. A prime candidate in this respect may be the FOOD sector. The above findings suggest, however, that increasing the pollution parameters for this sector only would change the results even less, especially where the FOOD sector is only small compared to the overall economy.

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