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The environment and welfare implications of trade and tax policy

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Abstract

Developing countries with comparative advantage in dirty industries face the risk of environmental degradation unless appropriate policies are implemented. Using applied general equilibrium analysis, we examine how trade influences the environment and assess the welfare and environmental implications of alternative pollution abatement policies for Indonesia. Our results indicate that unilateral trade liberalization by Indonesia would increase the ratio of emission levels to real output for almost all major pollution categories. More importantly, when tariff removal is combined with a cost-effective tax policy, the twin objectives of welfare enhancement and environmental quality improvement appear to be feasible. This sheds new and positive light on the role of trade in sustainable development.

JEL classification: F13; O53; Q28; Trade and environment; Pollution; Indonesia; Applied general equilibrium model

1. Introduction

International trade can exert an important influence on the environment via its effects on the composition of domestic production activities. Countries with less stringent environmental regulations may have comparative advantage in dirty industries. This leads to the export of 'pollution services' embodied in goods made with technologies that do not meet the environmental standards of the importing

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countries. In the course of trade, one observes pollution being transferred across a life cycle from more to less advanced nations. A number of empirical studies (e.g. Grossman and Krueger, 1992; Hettige et al., 1992; Lucas et al., 1992) have shown an inverse U-shaped relationship between GDP per capita and industrial pollution intensity. [1] The normal good characteristic of environmental quality, relatively high costs of monitoring and enforcing pollution standards, and an increase in output shares of manufactures during industrialization are some of the major factors leading to relatively high pollution levels per unit of output in developing countries (Birdsall and Wheeler, 1992).

Although there has been intense pressure from environmentalists and some policy makers to include environmental standards in trade agreements, economists have long argued that trade is not the root cause of environmental damage. Low and Safadi (1992) suggest that freer trade may provide benefits to the environment through its effects on resource allocation and income levels. Lucas et al. (1992) find that among developing countries, the more closed economies experienced very rapid shifts toward toxic-intensive structures in the 1970s and 1980s. This is because import-substituting industrialization protected mainly capital- and pollution-intensive sectors. Using partial equilibrium analysis, Anderson (1992) shows that even if a country has comparative advantages in the production of pollution-intensive goods, free trade would still raise welfare unambiguously, so long as an optimal pollution tax is introduced. Thus, previous studies suggest that trade does not necessarily lead to degradation of national environment, trade policy is never the first-best policy to remedy environmental problems, and an efficient environmental policy is one which would equalize marginal social costs and benefits of production. [2]

The objective of this paper is to show empirically that a combination of trade liberalization and a cost-effective tax policy would not only raise the country's welfare, but it can also improve the environmental quality. We use applied general equilibrium analysis to examine the environmental implications of trade and tax policies in Indonesia. This is a country well suited to our analysis because it has comparative advantages in dirty industries and its trade has historically conferred asymmetric environmental effects, inducing a net transfer of environmental costs from its trading partners, particularly Japan.

In Section 2, we present some statistics on the embodied pollution service trade between Indonesia and Japan during 1965–1990. Section 3 describes the two-country calibrated general equilibrium (CGE) model used in this study, followed

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[1] Hettige et al. (1992) and Lucas et al. (1992) suggest that the declining portion in the inverse U-shaped relationship is due solely to a shift from industry to services and not a result of a shift toward a less toxic mix of manufacturing output.

[2] See Dean (1992) for a survey of literature on trade and the environment. O'Connor (1994) reviews the recent Asian Pacific experience. A survey of Indonesia's trade and adjustment policies can be found in Roland-Holst (1992).

by the appraisal of the environmental implications of Indonesia's trade liberalization in Section 4 and the evaluation of the welfare effect of pollution abatement by alternative instruments in Section 5. Conclusions are summarized in Section 6.

2. International trade and patterns of effluent transfer

This section offers some historical evidence on how international trade influences the transfer of environmental effects. We introduce the concept of embodied effluent trade (EET) to capture the idea that traded commodities embody an environmental service, i.e. the amount of pollution emitted when goods are produced domestically. If countries impose different environmental costs on pollution, then the ability to pollute becomes a source of comparative advantage. One would thus expect to see a pattern with relatively high EET in exports from countries with low environmental standards and relatively low EET in their imports, while the opposite would prevail in countries with higher environmental standards. This is indeed the case for trade between Indonesia and Japan, which exhibits a striking imbalance in EET.

The database on the Industrial Pollution Projection System of the World Bank is used to measure domestic effluent intensities in production. It provides emission levels per unit of output for a variety of pollutants at a four-digit ISIC level of sectoral detail for US manufacturing. [3] The data are then mapped to four-digit output share data for Indonesia and Japan, computed from a 128-sector bilateral input–output table constructed by the Institute of Developing Economies (1991), to obtain weighted emission intensities for the 19 sectors of the model. [4] Table 1 presents the results of this conversion for Indonesia. [5]

As the database is limited to industrial pollution, agriculture and services are omitted from the effluent database. Since environmental damages related to agriculture and forestry, such as soil erosion and loss of soil fertility from deforestation are particularly important for Indonesia, their omission would understate the pollution content of domestic production. Of the remaining 17 sectors, petroleum, mining, lumber and wood, pulp and paper, industrial chemicals,

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[3] See Martin et al. (1991) and Wheeler (1992).

[4] Such detailed emission intensities are at the moment only available for US manufacturing sectors, obliging us to apply them to both Indonesia and Japan. The 19 sectors are (1) agriculture, forestry and fishing, (2) petroleum, (3) mining, (4) processed food, (5) textiles, (6) lumber and wood products, (7) pulp and paper products, (8) industrial chemicals, (9) other chemicals, (10) plastics, (11) non-metallic mineral products, (12) steel, (13) nonferrous metals, (14) metal products, (15) machinery and precision instruments, (16) electrical machinery, (17) transport equipment, (18) other manufactures, and (19) services.

[5] The results for Japan are similar to those for Indonesia although there are some differences in the emission intensities at the 19-sector level of disaggregation between the two countries because of different output shares at the four-digit ISIC level.

Table 1
Sectoral effluent intensities in Indonesia (tons/year/$million unless indicated otherwise)

	PARTIC [a]	*SO2*	*NO2*	*LEAD*	*VOC*	*CO*	*BOD* [b]	*SS*	*TOX* [c]	*METAL*
1 Agriculture	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2 Petroleum	5.36	16.28	3.47	6.54	1.60	0.65	0.48	0.58	1.15	0.06
3 Mining	4.19	20.12	1.65	0.40	2.05	19.76	8.17	117.64	4.05	2.79
4 Processed food	0.53	0.63	1.84	0.02	0.37	0.51	7.55	1.95	0.29	0
5 Textiles	0.40	2.83	4.91	0.00	1.20	0.93	0.02	0.03	1.49	0.07
6 Lumber and wood products	4.15	1.42	3.10	0.00	4.19	5.33	0	0	2.05	0.02
7 Pulp and paper	1.35	13.37	5.41	0.69	2.85	7.72	9.9	39.91	3.1	0.02
8 Industrial chemicals	0.61	4.09	3.95	0.03	4.15	5.60	9.41	21.09	13.57	0.08
9 Other chemicals	0.50	5.50	2.69	0.10	2.58	3.30	2.54	0.72	1.7	0.02
10 Plastics	0.14	1.36	40	0.00	4.52	0.12	0	0	3.39	0.09
11 Non-metallic mineral products	4.71	6.90	7.62	0.29	0.54	1.38	0	0	1.54	0.38
12 Steel	1.61	4.42	1.99	6.11	1.05	15.27	0.02	12.41	3.47	1.86
13 Non-ferrous metals	4.12	20.36	1.54	0.00	2.08	21.00	8.67	125.23	4.23	2.97
14 Metal products	0.25	0.17	0.82	0.22	4.23	0.09	0.55	11.71	2.08	0.3
15 Machinery & precision instruments	0.68	0.37	0.28	0.20	0.83	0.10	0	0	0.71	0.11
16 Electrical machinery	0.05	0.17	0.10	0.15	2.04	0.12	0	0.02	0.82	0.14
17 Transport equipment	0.15	0.09	0.06	0.00	0.85	0.02	0	0.01	0.5	0.02
18 Other manufactures	0.26	0.22	0.07	0.00	4.12	0.03	0	0	1.23	0.27
19 Services	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[a] Air pollutants: particulates (*PARTIC*), sulfur dioxide (*SO2*), nitrogen dioxide (*NO2*), lead (tons/year/$billion), volatile organic compounds (*VOC*), carbon monoxide (*CO*).
[b] Water pollutants: biochemical oxygen demand (*BOD*), suspended solids (*SS*).
[c] Toxic pollutants/all media: total toxic release (*TOX*), bioaccumulative metals (*METAL*).
Sources: Martin et al. (1991), Wheeler (1992), and authors' calculations.

non-metallic minerals (consisting of cement and stone products), steel, and nonferrous metals may be regarded as pollution-intensive sectors. For example, petroleum has high effluent intensities of particulates, SO_2, NO_2, and lead, while mining and nonferrous metals have high emission coefficients on particulates, SO_2, carbon monoxide, the two water pollutants (biochemical oxygen demand and suspended solids), and the two toxic pollutants (total toxic release and bioaccumulative metals).

Let ε_{ih} denote sectoral effluent intensities of pollutant h. To measure average effluent levels embodied in tradeable commodities, the acute human toxic linear (AHTL) index developed by Wheeler (1992) is used. The AHTL index is a weighted average of various effluents with weights representing their human health risk. The index of sectoral effluent output is defined as

$$e_i = \frac{\varepsilon_{i,A}}{\sum_i \varepsilon_{i,A} q_i}, \tag{1}$$

where $\varepsilon_{i,A}$ is the sectoral AHTL emission rate per unit of output in US manufacturing and q_i is sector i's share in total domestic output. If these indices are multiplied by 1985 US sectoral output shares, they sum to unity. For any other country, such a sum measures the effluent potential of domestic output in units relative to the United States. In 1985, for example, Japanese output shares give a value of $E_q = \sum_i e_i q_i = 0.86$, indicating that, under the same technologies, the effluent intensity of Japanese domestic production would be 14% below that of the United States by this index. The comparable figure for Indonesia is 2.45. Thus E_q serves as an index of aggregate effluent levels for a given composition of domestic production. As the structure of the economy shifts toward relatively cleaner activities, such as services, this index will decline. It is unaffected by the absolute level of output, but simply allows comparison across countries of one representative unit of domestic product.

In light of differing environmental standards in the two countries, the disparity in E_q is likely to be greater than the indices would indicate. Japan's effluent controls are more stringent than those of the US, and thus the compositional index for the former is likely to overstate Japanese effluent levels. Likewise, Indonesia's environmental controls are weaker than the reference country, so its actual effluent levels are underestimated by E_q.

This measure can also be used to evaluate the implicit effluent content of trade. The indices

$$E_x^f = \sum_i e_i x_i^f \tag{2}$$

and

$$E_m^f = \sum_i e_i m_i^f \tag{3}$$

measure the embodied effluent content of exports and imports, respectively; x_i^f

Table 2
Trends in embodied effluent content of exports and imports [a]

	1965	1970	1975	1980	1985	1990	Average
Indonesia							
Exports to							
Japan	11.32	11.45	15.34	13.43	11.77	10.41	12.29
Rest of world	7.28	6.49	14.14	12.20	10.59	7.23	9.66
Imports from							
Japan	2.10	2.17	2.03	1.80	1.99	1.67	1.96
Rest of world	2.29	2.73	2.79	4.44	4.16	3.34	3.29
Effluent trade ratio (E_x / E_m)							
Japan	5.38	5.29	7.57	7.47	5.93	6.24	6.31
Rest of world	3.18	2.38	5.06	2.75	2.54	2.17	3.01
Japan							
Exports to							
Indonesia	2.10	2.17	2.03	1.80	1.99	1.67	1.96
Rest of world	1.75	1.62	1.69	1.60	1.52	1.54	1.62
Imports from							
Indonesia	11.32	11.45	15.34	13.43	11.77	10.41	12.29
Rest of world	4.09	3.87	7.63	8.86	7.39	4.78	6.10
Effluent trade ratio (E_x / E_m)							
Indonesia	0.19	0.19	0.13	0.13	0.17	0.16	0.16
Rest of world	0.43	0.42	0.22	0.18	0.21	0.32	0.30

[a] These indices measure embodied effluent content of exports and imports relative to the emission intensity of overall US domestic output. Values greater than unity imply that the country's overall exports by destination or imports by origin are more pollution-intensive than the US output.
Sources: Wheeler (1992), United Nation's COMTRADE database, and authors' calculations based on Eq. (2) and Eq. (3) in the text.

and m_i^f are the sectoral shares of exports to destination f (f = bilateral partner, rest of world (ROW)) and the sectoral shares of imports from origin f. If E_x^f exceeds unity, for example, the composition of the country's existing exports represents (in their production) a higher level of pollution per unit than that of the representative output in the United States. Values less than unity mean that the country's overall exports are 'cleaner' than overall US domestic output.

The indices E_x and E_m thus measure the embodied effluent trade for a given composition of exports and imports per unit of trade. E_x and E_m for Indonesian–Japanese bilateral trade and their trade with the rest of the world are presented in Table 2. These estimates were constructed for the 1965–1990 period at five-year intervals, with detailed trade data from the United Nation's COMTRADE tables. The ratios of E_x to E_m are also given in the table. [6]

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[6] The pollution content of US exports and imports has been estimated by Walter (1973). He estimated environmental-control loadings entering US trade flows and found that the pollution content of US exports exceeded that of imports in 31 out of 78 sectors in 1971.

The most arresting feature of Table 2 is the imbalance in direct EET between the two trading partners. Over the last two and a half decades, Indonesia's production for export to Japan has been about six times more effluent intensive than have Japanese exports to Indonesia. In a long-term situation of relatively balanced bilateral trade, this implies a sustained and significant transfer of environmental costs from Japan to Indonesia. Although the trend in recent years has reduced this disparity, it is still quite significant.

These results are even more striking when compared to each country's trade with the rest of the world. Indonesia's imports from Japan are about half as effluent intensive as what it buys from other countries and its exports to Japan are about 30% as effluent intensive as other countries' exports to Japan. Trade between countries at different stages of modernization has long exhibited hierarchical properties which are correlated with technology levels and environmental effects.

Given that the effluent indices are derived assuming US technology and environmental standards, economic structure alone could explain Indonesia's higher pollution intensities in production, both for domestic and foreign consumption. There are significant differences in sectoral and trade structure between the two countries. Indonesia's heavy export dependence on petroleum (64% of total exports in 1985) is the dominating factor for its high effluents embodied in overall exports. On average, the petroleum sector has been responsible for more than 50% of Indonesia's industrial emissions and about 90% of the EET in exports. Lumber and wood and nonferrous metals have each accounted for between 3 and 4% of the effluents embodied in exports. [7] By contrast, except for steel, Japan's exports are concentrated in sectors with low pollution intensities, resulting in low effluents embodied in its exports. Thus, the composition of output in Indonesia is substantially more pollution intensive than that in Japan. [8]

3. Two-country CGE model for Indonesia and Japan

Calibrated general equilibrium models have been increasingly used as tools for detailed empirical analysis of the long-run implications of economic policy. They

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[7] Because log exports were banned in 1985, the production and exports of wood products have increased sharply. In our industrial classification, logging is included in agriculture where no emission data are incorporated. Thus, a shift in exports from logs to lumber and wood products would also raise the value of embodied effluent content of Indonesian exports although the export ban could slow deforestation.

[8] Since the US effluent coefficients are applied to Indonesia and Japan, differing levels of technology and environmental regulations between the two countries do not affect our results. If country-specific data were available, the results would have yielded even larger asymmetries. There are significant technological disparities between the two countries in a variety of industrial activities, with Japan's environmental regulation being more stringent than Indonesia's.

have been used extensively in general equilibrium assessments of CO_2 abatement policies (e.g. Burniaux et al., 1992; Jorgenson et al., 1992; Perroni and Rutherford, 1993; OECD, 1994). Because a CGE model can distinguish dirty industries and capture a variety of indirect effects, such as interindustry and trade linkages, it is well suited to analyzing the impact of trade and tax policy on the environment and economic welfare.

The Indonesia–Japan CGE model is calibrated to the 1985 social accounting matrix (SAM) of the two countries.[9] An important feature of this model is its endogenous specification of domestic supply, demand, and bilateral trade for the two countries at the sectoral level. This is particularly important for Indonesia as its bilateral trade with Japan as a percentage of the total trade was 47% for exports and 21% for imports in the base year. While trade between the two countries is modeled endogenously, we assume that their individual trade flows with the rest of the world (ROW) are each governed by the small country assumption.[10] The resulting six sets of sectoral trade flows are then directed by two endogenous price systems (Indonesia–Japan imports and exports), and four exogenous price systems (Indonesia–ROW and Japan–ROW imports and exports).

As has been employed in many other CGE models, a differentiated product specification is used for the demand and supply for tradeable commodities. Domestic demand is a CES composite of goods differentiated by origin. For each product category,

$$D_i = \bar{A}_{D_i}\left[\sum_k \beta_i^k \left(D_i^k\right)^{(\sigma_i - 1)/\sigma_i}\right]^{\sigma_i/(\sigma_i - 1)} \tag{4}$$

where $k = \{\text{Indonesia, Japan, ROW}\}$. D_i^k consists of domestic goods, imports from the bilateral trading partner, and imports from ROW, σ_i is elasticities of substitution among D_i^k, and $\bar{A}_{D_i}$ and β_i^k are intercept and share parameters. Similarly, domestic production is supplied to differentiated destinations (domestic market, exports to bilateral partner, and exports to ROW), which is specified as a CET composite:

$$S_i = \bar{A}_{S_i}\left[\sum_k \delta_i^k \left(S_i^k\right)^{(\lambda_i + 1)/\lambda_i}\right]^{\lambda_i/(\lambda_i + 1)} \tag{5}$$

where λ_i is elasticities of transformation among S_i^k, and $\bar{A}_{S_i}$ and δ_i^k are intercept and share parameters.

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[9] See Lee and Roland-Holst (1993b) for a complete set of equations describing the model.

[10] Lee and Roland-Holst (1993a) treat Japan as a large country so as to affect prices in the ROW market. For the moderate trade flow adjustments for Japan described in this study, however, the small country assumption makes almost no change in the results of simulation experiments.

Every sector is characterized by constant returns to scale and perfect competition.[11] The production function is given by

$$S_i = \min\left\{CES\left(L_{D_i}, K_{D_i}; \phi_i\right), V_{1i}/a_{1i}, \dots, V_{ni}/a_{ni}\right\}, \tag{6}$$

where L_{D_i} and K_{D_i} are labor and capital demands, ϕ_i is the elasticities of substitution between labor and capital, a_{ji} is input–output coefficients, and $V_{ji} = a_{ji}S_i$ is demand for intermediate good i in sector j. The zero-profit condition implies

$$\left(1 - t_{S_i}\right)P_{S_i} = AC_i, \tag{7}$$

where P_{S_i} and AC_i are prices and average costs of composite supply.[12]

Ad valorem tax rates on supply, t_{S_i}, are the sum of ad valorem indirect taxes, t_{X_i}, and ad valorem effluent taxes:

$$t_{S_i} = t_{X_i} + \sum_h \tau_{ih}\varepsilon_{ih}, \tag{8}$$

where τ_{ih} are excise taxes on emissions ($/ton of pollutant h).

We assume both countries have a fixed aggregate stock of domestic productive capital which is mobile between sectors, while the economy-wide average rental rate adjusts to equate aggregate capital demand to the fixed total supply. We also assume that labor in both countries is mobile between sectors, but the total labor supply is specified as a function of the wage rate and household income. In the product markets, prices are normalized by a fixed numéraire chosen to be the GDP price deflator. Finally, we assume that the real exchange rate is flexible while the current account balances for the two countries are fixed at the baseline values.[13]

Sectoral emission levels by pollutant and destination of supply are computed as

$$EMI_{ih}^k = \varepsilon_{ih} P_{S_i}^k S_i^k. \tag{9}$$

The matrix of effluent intensities by sector and type of pollutant, $\{\varepsilon_{ih}\}$, forms the basis for calculating environmental effects resulting from policy changes, such as tariff liberalization and effluent taxes. A limitation of this approach at the moment is that there is no scope for technical substitution within sectors, and thus emissions are proportional to output regardless of relative prices and differential effluent taxes. The main advantage of this approach over previous modeling with these coefficients is the general equilibrium nature of the simulations, which allow

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[11] While varying returns to scale does affect the magnitude of impact of trade and tax policies, the key results of this paper are robust and not affected by different specifications on market conduct (e.g. oligopolistic behavior) and returns to scale.

[12] The composite supply price is given by $P_{S_i}S_i = \Sigma_k P_{S_i}^k S_i^k$.

[13] Since there are no assets in the model, the real exchange rate is the relative price of tradeables to nontradeables.

Table 3
Aggregate results of Indonesia's tariff liberalization (percentage changes)

	Indonesia	Japan
Real GDP	0.87	0.00
EV income	0.53	0.03
Wage rate	1.10	0.05
Employment	1.87	0.00
Rental rate on capital	3.31	0.04
Real exchange rate	5.26	−0.07
Total imports	5.81	0.14
Total exports	5.72	−0.07

for changing composition of domestic output, a large medium-term source of pollution mitigation.[14]

4. Trade and domestic pollution in Indonesia

The two-country CGE model is used to assess the linkage between trade and the environment by removing Indonesia's nominal tariffs on all imports. Table 3 summarizes the aggregate results. The tariff removal leads to an increase in Indonesia's real GDP by 0.87% and economy-wide employment by 1.87%. Equivalent variation (EV) income, which measures the change in real consumer purchasing power, rises by less than the increase in real GDP because of a fall in the bilateral terms of trade with Japan.[15] The wage rate and the rental rate on capital both increase, but the latter increases more because an increase in labor supply in response to higher wages raises the marginal productivity of capital. Indonesia's tariff removal induces real rupiah depreciation and the subsequent increase in its exports. It has a negligible effect on the Japanese economy, with all aggregate measures changing by a small fraction of one percent.

Trade liberalization leads to dramatic shifts in the composition of Indonesia's sectoral trade and output that are driven by sharp changes in relative prices. It induces an expansion of output in petroleum and mining, lumber and wood, nonferrous metals, and services.[16] The real rupiah depreciation leads to increased demand for Indonesian exports in most of the major sectors.[17] Results for Japan are again small, except for adjustments in bilateral trade with Indonesia. There is

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[14] Compare to e.g. Anderson (1992) and ten Kate (1993).

[15] The terms of trade with the rest of the world are unaffected because of the small country assumption.

[16] The sectoral results are available upon request from the authors.

[17] The sectors that experience a fall in exports (pulp and paper, non-mineral metallic products, steel, and metal products) have small export shares.

Table 4
Changes in emission levels by destination of supply: Indonesia [a]

	Absolute changes [b]				Percentage changes			
	(1) Domestic	(2) Japan	(3) ROW	(4) Total	(5) Domestic	(6) Japan	(7) ROW	(8) Total
PARTIC	773	2298	2297	5369	0.89	4.94	7.40	3.27
SO2	2461	7146	6338	15945	1.04	5.01	7.23	3.41
NO2	−209	1443	1619	2853	−0.24	4.89	6.96	2.04
LEAD	1.17	2.54	2.23	5.94	1.57	4.79	7.02	3.73
VOC	−599	747	1029	1178	−1.15	5.07	7.80	1.47
CO	−778	1112	1307	1641	−1.20	6.71	9.49	1.73
BOD	−657	536	608	487	−0.83	6.43	8.66	0.51
SS	−1497	5094	3973	7571	−0.76	7.66	11.71	2.55
TOX	−368	649	951	1232	−0.89	5.46	9.38	1.95
METAL	−62	137	106	181	−0.91	6.99	9.80	1.83
AHTL index	−0.10	1.17	1.56	2.64	−0.16	5.16	8.76	2.64

[a] Changes in emission levels of pollutant embodied in output supplied to different destination resulting from unilateral tariff liberalization by Indonesia.

[b] Absolute changes in thousand tons of pollutant except the AHTL index.

some shift of resources toward Japanese export sectors and a slight diversion of import demand in response to the rupiah depreciation.

While removing tariff protection leads to expanded trade and greater economy-wide efficiency, in the absence of new technologies it entails an increase the total emission levels. Tables 4 and 5 report the effects on emission levels of each

Table 5
Changes in emission levels by destination of supply: Japan [a]

	Absolute changes [b]				Percentage changes			
	(1) Domestic	(2) Indonesia	(3) ROW	(4) Total	(5) Domestic	(6) Indonesia	(7) ROW	(8) Total
PARTIC	−1058	51	−49	−1057	−0.08	2.82	−0.07	−0.08
SO2	−3619	83	−147	−3683	−0.10	1.58	−0.07	−0.09
NO2	−520	84	−38	−473	−0.03	2.97	−0.04	−0.03
LEAD	−0.96	0.01	−0.05	−1.00	−0.09	0.70	−0.06	−0.09
VOC	−417	83	−72	−406	−0.03	2.77	−0.06	−0.03
CO	−2111	50	−221	−2282	−0.06	0.67	−0.08	−0.06
BOD	−495	25	−46	−517	−0.02	1.05	−0.07	−0.02
SS	−9796	126	−638	−10309	−0.09	0.75	−0.12	−0.09
TOX	−550	56	−72	−565	−0.04	1.45	−0.06	−0.03
METAL	−276	9	−30	−297	−0.06	1.00	−0.08	−0.06
AHTL index	−0.64	0.08	−0.12	−0.69	−0.03	1.11	−0.05	−0.03

[a] Changes in emission levels of pollutant embodied in output supplied to different destination resulting from unilateral tariff liberalization by Indonesia.

[b] Absolute changes in thousand tons of pollutant except the AHTL index.

pollutant embodied in domestic output supplied to different destination (domestic market, bilateral partner, and ROW). Given the extensive compositional shifts in production that occur in response to trade liberalization in Indonesia, emissions from the production of goods supplied domestically increase for three pollutants (particulates, SO_2, and lead) while those decrease for the other pollutants (column (1) of Table 4). In percentage terms, these changes are relatively small (column (5)). Trade expansion would, however, increase emissions quite substantially from the production of goods that are exported to both Japan and the rest of the world for all pollution categories included in the study (columns (2)–(3), (6)–(7)). The net effect is an increase in the emission level of all the pollutants generated from total output (columns (4), (8)). Table 5 reports the effects on emissions from output produced in Japan resulting from Indonesia's tariff removal, which are significantly smaller than those in Indonesia in percentage terms.

The result that trade liberalization leads to higher pollution levels is not surprising because it leads to an increase in real output. A more interesting result is that it leads to an increase in the relative output shares of dirty industries, causing higher average pollution intensities for almost all major pollution categories. The only exception is biochemical oxygen demand (water pollution) whose emission level rises by a smaller percentage (0.51%) than the increase in real output. For all other pollutants, the percentage change in emission levels (1.43–3.73%) exceeds the percentage change in real output, resulting in higher emission intensities.

5. Relative cost of alternative trade and tax policies in curtailing pollution

For Indonesia, the emission results of Section 4 amplify the policy challenge of addressing the environmental consequences of trade-based economic growth. If the marginal social damage caused by an increase in emissions of a particular pollutant is known, then in the absence of other distortions in the economy an optimal policy would be the imposition of an effluent tax which would internalize the social damage (Pigou, 1920). However, true marginal damage is unknown, and reliable estimates on marginal damage functions associated with externalities are unavailable. This is an important direction for future research as economic accounting of environmental costs and benefits would be essential for comprehensive integration of economic and environmental policies. [18]

Since the uncertainties on marginal benefits of pollution abatement would make the calculation of an optimal tax rate impossible, our approach is to set a particular level of emission target and assess empirically the relative cost of alternative

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[18] For a survey of this kind of environmental valuation, see O'Connor (1992).

instruments that achieve the target.[19] In the first three experiments, we evaluate the cost of mitigating emissions of various pollutants by 5% using three policy instruments: an export tax, sector-specific effluent taxes, and a uniform effluent tax.[20] Different abatement targets have also been tried, but the relative efficiency of these instruments were not affected by the choice of abatement targets. No taxes are levied on the agricultural or service sector because no emission data are incorporated for these sectors. An AHTL (human health risk index) tax is equivalent to a set of taxes on the major air pollutants (particulates, SO_2, NO_2, lead, volatile organic compounds, and carbon monoxide) which act to reduce the AHTL index by 5%. In the fourth experiment, the combination of a uniform effluent tax and tariff removal is simulated to evaluate whether it is possible to increase real output and reduce emissions at the same time. While these experiments were conducted for each pollutant, for simplicity we only report the aggregate results for SO_2 and the AHTL index in Table 6.[21]

In the first experiment, an export tax is chosen as a policy instrument because in Indonesia exports are on average considerably more pollution intensive than goods supplied domestically (Section 2). Since the root cause of the pollution problem is production (regardless of destination), however, the imposition of a tax only on exports would be less efficient than a tax on output supplied domestically and exported. Columns (1a) and (1b) of Table 6 indicate that the cost of achieving the emission target with an export tax, in terms of lost real GDP or EV income, is highest among the three policy instruments. The reduction in total exports is partly offset by a large real depreciation of the rupiah but is still over 10% of the baseline quantity. The sharp contraction of trade causes additional reduction in real GDP and EV.

In experiment 2, sector-specific effluent taxes are levied to lower SO_2 emissions or the AHTL index by 5% in every sector.[22] While effluent taxes are imposed on all output regardless of destination, an enforcement of the same abatement target in all industrial sectors imposes an extremely high cost on some. This is clearly illustrated in Table 7, which summarizes the sector-specific SO_2

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[19] An optimal rate of effluent tax would equalize marginal damage and marginal abatement cost of 1 ton of pollutant. On the cost side, Hartman et al. (1994) provide comprehensive estimates on abatement of 7 air pollutants for 37 US manufacturing industries.

[20] Since our primary objective is the evaluation of the combined effects of trade liberalization and cost-effective tax policy, we limited the number of tax instruments to three. For evaluation of alternative policy instruments, such as pollution abatement and control expenditure (PACE) equalization tax and the polluter-pay principle, see Low (1992) and Low and Safadi (1992).

[21] SO_2 is chosen because it is a pollutant that is known to adversely affect local environmental conditions, including acidification of soils and water and corrosion of materials.

[22] Sector-specific taxes required to mitigate emissions by 5% will lead to the same results regardless of the pollutant chosen except for the effluent tax results, which depend upon the effluent intensities of the pollutant in different sectors.

Table 6
Aggregate results for alternative trade and tax policies (percentage changes)

	Export tax [a]		Sector-specific effluent taxes [b]	Uniform effluent tax [c]		Uniform tax and liberalization [d]	
	(1a)	(1b)	(2)	(3a)	(3b)	(4a)	(4b)
	SO_2	AHTL		SO_2	AHTL	SO_2	AHTL
Real GDP	−1.65	−2.26	−1.22	−0.56	−0.54	0.30	0.33
EV income	−1.18	−1.67	−1.14	−0.34	−0.45	0.25	0.14
Employment	−3.07	−3.99	−2.46	−0.15	−0.97	1.82	0.92
Wage rate	−2.53	−3.57	−2.16	−1.15	−1.09	0.03	0.14
Rental rate on capital	−5.75	−7.68	−5.46	−2.49	−2.78	0.80	0.56
Real exchange rate	17.67	24.70	4.81	3.61	3.54	9.02	9.03
Total imports	−11.87	−15.58	−1.94	−1.45	−1.47	4.20	4.09
Total exports	−10.87	−14.25	−2.26	−2.15	−1.64	3.31	3.81
SO_2 emissions	−5.00	−6.42	−5.00	−5.00	−3.74	−2.03	−0.61
AHTL index	−3.98	−5.00	−5.00	−3.44	−5.00	−1.10	−3.07

[a] (1a) export tax to cut SO_2 emissions by 5%; (1b) export tax to lower the AHTL index by 5%.

[b] Sector-specific effluent taxes to lower SO_2 emissions or the AHTL index by 5% in every sector.

[c] (3a) uniform effluent tax to cut SO_2 emissions by 5%; (3b) uniform effluent tax to lower the AHTL index by 5%.

[d] (4a) combination of (3a) and tariff removal; (4b) combination of (3b) and tariff removal.

taxes required to achieve alternative emission targets within each sector. These taxes approximate the marginal cost of mitigating SO_2 emissions compared with the baseline levels for each sector.[23] SO_2 abatement costs in metal products, transport equipment, and other manufactures are found to be more than 400 times those in industrial chemicals. Thus, regulation which would require every sector to cut emissions by the same proportion would be highly inefficient.

Given the large disparity in marginal abatement costs, a uniform effluent tax would significantly reduce the costs of achieving a given emission curtailment target (experiment 3). The cost of cutting SO_2 emissions by 5% in terms of a loss in real GDP under a uniform tax is less than half (0.56 vs. 1.22%) compared with sector-specific taxes (Table 6, columns (2) and (3a)). Under this scheme each sector will abate SO_2 until the marginal abatement cost is equal to the uniform tax

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[23] These are not directly comparable with the econometric estimates on US sectoral marginal abatement costs by Hartman et al. (1994). As in other CGE models, our estimates take into account input–output linkages but are based on the database of the benchmark year (1985) and the embedded model structure.

Table 7
Summary of SO_2 tax results under alternative emission targets ($/ton of SO_2 at 1985 prices and 1985 exchange rate)

Sector-specific taxes	Emission reductions compared with the baseline				
	1%	3%	5%	7%	10%
1 Agriculture	n.a.	n.a.	n.a.	n.a.	n.a.
2 Petroleum	1.05	3.07	5.01	6.87	9.50
3 Mining	1.16	3.39	5.51	7.52	10.34
4 Processed food	30.20	89.87	148.59	206.40	291.49
5 Textiles	3.65	10.83	17.85	24.71	34.70
6 Lumber and wood	14.21	42.00	68.96	95.09	132.75
7 Pulp and paper	0.70	2.05	3.36	4.61	6.39
8 Industrial chemicals	0.22	0.60	0.93	1.20	1.48
9 Other chemicals	4.27	12.64	20.78	28.69	40.14
10 Plastics	11.63	34.85	58.05	81.25	116.12
11 Non-metallic mineral products	5.89	16.85	26.79	35.78	47.65
12 Steel	3.55	10.40	16.90	23.07	31.70
13 Nonferrous metals	0.34	0.99	1.61	2.19	3.02
14 Metal products	89.25	262.54	429.05	588.94	816.70
15 Machinery and precision instruments	17.64	52.66	87.35	121.71	173.03
16 Electrical machinery	47.47	139.98	229.23	315.23	438.08
17 Transport equipment	87.66	259.92	428.18	592.51	831.85
18 Other manufacturing	90.97	270.54	446.95	620.20	874.09
19 Services	n.a.	n.a.	na.	n.a.	n.a.
20 Weighted average [a]	1.79	5.27	8.62	11.85	16.46
21 Uniform tax	0.74	2.19	3.61	4.99	7.02

[a] The sectoral SO_2 emission shares are used for the weights.

rate. Thus, the industrial chemical and nonferrous metal sectors will abate more than 10% of SO_2, pulp and paper over 5%, and petroleum and mining between 3 and 5% (Table 7). Many high abatement cost sectors will not abate any SO_2 emissions at all. The uniform tax rate required to achieve a given target is also substantially lower than the emission weighted average of the sector-specific taxes (Table 7, rows 20 and 21).

While a uniform effluent tax will tend to minimize the cost of a given mitigation target, those sectors with low marginal abatement cost would bear much of the cost in terms of loss in real output. A system of tradeable emission permits is an alternative cost-effective instrument to a uniform tax, but which can be more supportive to equity issues. Under this system a fixed number of permits to emit a specified quantity of the pollutant is issued to emitters. Those firms or sectors with low abatement cost can sell permits to those with high abatement cost at a market-clearing permit price, thereby receiving compensation for further abatement in emissions. The equilibrium permit price is determined by demand and supply of permits, which should equal the uniform tax rate required to achieve the same emission curtailment target. In the absence of transaction costs and regulatory distortions, a uniform tax and tradeable emission permits would both achieve a given level of environmental quality at minimum cost. [24]

In the final experiment, the same uniform tax scheme implemented in the third experiment is combined with the removal of all tariffs. This experiment is conducted to illustrate a critical point that the combination of trade liberalization and a cost-effective emission abatement instrument can lead to both an improvement in welfare (in terms of real GDP or EV) and a reduction in pollution (Table 6, columns (4a) and (4b)). This is possible because the benefits of tariff removal are greater than the cost of cutting pollution by the magnitude which more than offsets pollution induced by trade liberalization. The twin objectives of a welfare improvement and an emission curtailment can be achieved under a range of ex ante abatement targets for each pollutant. For SO_2, for example, the implementation of an ex ante abatement target of between 3.2 and 7.4% by a uniform tax, combined with complete tariff removal, will lead to realization of both objectives. It should be recalled that no pollution externalities have been introduced in our model because of the uncertainties regarding marginal damage. In the presence of externalities, therefore, the net social benefits of the combined policy would be even greater than our estimates would suggest.

6. Conclusions

Indonesia's historical trade orientation has been environmentally asymmetric, effecting significant transfers of pollution services from its trading partners, particularly Japan, to the domestic economy. While trade liberalization would improve Indonesian real income, it would also raise the emission level of major industrial pollutants. In light of this tradeoff between outward-oriented industrialization and the environment, we have assessed the relative cost of curtailing pollution with a variety of instruments, including export taxes, sector-specific effluent taxes, and uniform effluent taxes. In addition, a combination of uniform tax and tariff removal is simulated to examine the possibility of lowering domestic emissions and raising material welfare simultaneously.

Our simulation results indicate that a uniform effluent tax is the most cost-effective instrument in abating SO_2 emissions. This result holds for abatement of other industrial pollutants and for different abatement targets. Neither the imposition of an export tax, nor uniform emissions reduction with sector-specific taxes are recommended as an alternative policy. Pollution abatement using these instru-

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[24] Hahn and Stavins (1992) point out that these incentive-based approaches are not well suited when there are political and technological constraints. For example, source-specific standards may be more appropriate for highly localized pollution problems with nonlinear damage functions. It is beyond the scope of this study, however, to incorporate such additional features as emission source type and political constraints.

ments would result in a loss of real GDP that is significantly greater than achieving the same target using a uniform effluent tax.

The most important result of this paper is that it is possible to abate industrial pollution while maintaining or even increasing real output when uniform taxation is combined with trade liberalization. In other words, trade liberalization should not be discouraged because of its environmental effects, and environmental taxation need not be contractional if distortions can be removed elsewhere. While the present model does not incorporate the benefits of reduced pollution in the utility function or EV calculation, their inclusion would only strengthen our conclusion.

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