Is There a Trade-Off Between Trade Liberalization and Environmental Quality? A CGE Assessment on Thailand

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This article explores the question of whether there is a trade-off between trade liberalization and environmental quality. Using a computable general equilibrium framework, the author examines the economic, environmental, and welfare impacts of alternative policy scenarios, including a tariff reduction scenario, a carbon tax scenario, and a combined trade and environmental reform scenario. The results of the analysis, in the case of Thailand, show that if the country were to pursue greater trade liberalization alone without a concomitant increase in pollution abatement, there is a modest but real risk that it will become more specialized in dirty activity. If the country pursued pollution abatement without further trade liberalization, the cost in terms of growth does not appear to be significant. When environmental and trade policies are jointly considered, greater substitution away from the polluting energy inputs is observed with the cost on economic growth remaining insignificant.

Keywords: *climate change; carbon dioxide emissions; ancillary benefits; trade policy; carbon tax; CGE analysis; developing nations; Thailand*

Trade and environment linkages have been studied by many. Earlier key conclusions include that the use of trade instruments to address environmental pollution is inefficient and that even in a second-best world, the optimal policy to abate emissions should be to directly address the emissions of pollutants (Bragga, 1992; Carraro, 1999; Corden & Falvey, 1985; Kennedy, 1994). A number of papers contributed to the earlier understanding of whether there is a trade-off between further trade liberalization and environmental quality and whether there is a differentiation based on developed countries versus developing countries. Qualitative results in the literature concerning these issues have

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given mixed answers (Kraus, 2000; Ulph, 1996a, 1996b, 1999). Quantitative or empirical research confirms that developing economies tend to specialize in dirty industries (Birdsall & Wheeler, 1992; Hettige, Lucas, & Wheeler, 1992; Lee & Roland-Holst, 1997; Low & Yeats, 1992; Siebert, 1974). Yet empirical studies do not find strong evidence that Organisation for Economic Co-operation and Development (OECD) countries' stricter environmental regulation on its own has reduced their competitiveness (OECD, 1993; Perroni & Wigle, 1994; Tobey, 1990).

More recently, the work of Copeland and Taylor (1993, 1994, 2003), Cole and Elliott (2003, in press), Cole (2004), and Kuik and Gerlagh (2003) have contributed to another round of important conclusions with regard to trade and environment linkages. Among others, they have brought to light the importance of capital-labor ratio or relative factor endowments in explaining trade in dirty goods. Their empirical findings show that factor abundance motives for trade in dirty goods are much more important than pollution-haven motives. With regard to developing countries, based on their findings, those that are capital scarce (which most of them are) do not automatically experience an increased share of dirty production under freer trade; however, those that are relatively capital intensive and have relatively relaxed environmental regulations are the likeliest to become pollution havens. The story on the developed countries' side is also not clear-cut but again highly interesting. The reader is encouraged to look into the cited literature on that.

The current study is not a global study and, therefore, cannot be used to assess north-south trade flows as they relate to environmental regulations and/or further trade liberalization. Rather, it is a country-level study for a developing country, Thailand, whose economy is highly open and fairly capital intensive. For such an economy, the author wants to assess the impacts of further trade concessions and/or environmental regulation on its economy and welfare distributions. This would contribute to a further understanding of trade and environment linkages for a small open economy that is relatively capital intensive compared to other developing countries. To do so, the author uses the analytical tool of a computable general equilibrium (CGE) model.

Thailand is a small open economy; the openness of the Thai economy has averaged more than 45% in recent years, making it very sensitive to its trade policy reforms. Thailand has progressively reduced tariffs during the past decade. Based on the documentation of the United Nations Conference on Trade and Development (2003), as of January 2003, Thailand had fully implemented the Uruguay Round Final Schedule on tariff concessions. In the most difficult category of agriculture, Thailand progressively reduced tariffs on 746 items to reach a 24% reduction on them by 2004. Thailand also eliminated tariffs on 153 categories of products (including computers, calculators, transistors, and machinery and equipment in the manufacturing of semiconductors) in 2000 and would remove tariffs on 37 additional products to zero by 2005 (fax machines, fiber optic cable, etc.). More generally, the Ministry of Finance plans to streamline the existing tariff structure and reduce tariffs on intermediate and finished products by 50%. These form the basis for the consideration of a 25% tariff reduction scenario from the 1998 benchmark. Because the tariff reduction scenario is considered in a single-country model, it is isolated from the multilateral trade reduction scheme of the World Trade Organization. The results therefore reflect a conservative assessment of the economic gains for Thailand from its additional trade concessions, because, in reality, granting preferential access to Thailand's market (through additional trade concessions) would grant Thailand similar access to other economies as well.

The current industrial structure in Thailand relies heavily on fossil fuel burning, which causes the emission of a major greenhouse gas (GHG), CO_2, and an important local air pollutant, PM-10[1]. Although Thailand is a non-Annex I country and therefore is not obligated to reduce GHG emissions, several reasons contribute to considering a GHG reduction policy scenario for Thailand. Thailand was one of the first signatory countries to the United Nations Conference on Climate Change in 1992 and was again one of the first countries to ratify the convention by doing so in 1995. Based on its *Initial National Communication Under the United Nations Framework Convention on Climate Change* (Zola & Lim, 2000), between 1994 and 2000, Thailand implemented a range of measures (including demand side management, excise taxes, and carbon sequestration) that led to close to a 15% reduction from what would otherwise have been the total level of GHG emissions (Zola and Lim, 2000). Further reduction has occurred since 2000 because of the implementation of additional measures proposed under the *Communication*. Thailand's contribution to GHG reduction has been the result of pursuing no-regret policies that lower GHGs and vulnerability to climate change through greater energy efficiency and better management of natural resources. An additional incentive has been highlighted in recent literature for Thailand to reduce fossil fuel consumption; even with modest reduction in fossil fuel consumption, there would be large health gains through local air quality improvement (Li, 2002a, in press). Capacity building and technology transfers measures are also underway to facilitate Thailand's continuous reduction in its GHGs. For these reasons, we consider a scenario of further GHG emission reduction.

The major sectors emitting CO_2 in Thailand are the energy-intensive manufacturing industries (including electric power generators) and

1. Epidemiological studies have found that the mass concentration of particles with aerodynamic diameters less than 10μm (PM-10) represents a good measure for health hazards resulting from particulate air pollution.

transport industries. Energy-intensive manufacturing there takes up 30% of total industrial output but 54% of total CO_2 emissions. Second, the transport industries contribute 36% of total CO_2 emissions while generating 27% of industrial output. Emissions of the local air pollutant, PM-10, are most closely associated with fossil fuel consumption. In urban areas, it is largely associated with vehicle use (54% contribution), with less contribution from point sources or industries (only 10% contribution); the rest is considered background or area contribution.[2] Industrial combustion and process-generated PM-10 emissions are substantial on the aggregate level but usually are more dispersed.

Environmental abatement policies such as a carbon tax and trade liberalization have different implications for the environment and economy. A carbon tax imposes additional costs on fossil fuel consumption and induces end users to buy less gasoline and diesel and producers to substitute nonfossil-fuel energy or nonenergy inputs for fossil fuel inputs. By making energy intermediate inputs more expensive, a carbon tax could have the implications for trade by modifying the export competitiveness of the economy. By contrast, a trade liberalization policy would open up the economy for further competition with foreign producers and induce more efficient production; yet it can also imply an increase in polluting productions. In this article, our goal is to compare the impacts of these policies on Thailand. We simulate a carbon tax policy and investigate its effects on the growth, sectoral allocations, trade or international competitiveness, and the environment on the Thai economy. Then, we simulate a reduction in tariff to examine whether it leads to a specialization in dirty production activities. Finally, we examine the impact on international competitiveness and environmental performance of a joint policy scenario.

Two main aspects of the CGE model presented in this article are crucial. First, most economy-wide studies on growth and environment linkages rely on effluent intensities with output, but do not allow substitution between nonpolluting and polluting primary inputs. Abating pollution in these cases is achieved primarily by reducing output in pollution-intensive sectors, with a significant cost in terms of economic growth. In contrast, in the current model, pollution emissions are linked to polluting input use, rather than output generated. The technical adjustment made by producers by substituting nonpolluting factors for polluting factors can therefore be assessed.

Second, this model embodies a high level of disaggregation for products, sectors, types of pollution emitted, and types of household. This allows the tracking of the economic and environmental effects as the var-

2. Based on personal conversation with Ms. Suwimol Wattanawiroon, an environmental officer at the Industrial Air Pollution Subdivision of Pollution Control Division, Bangkok, Thailand.

ious sectors expand and contract, given a policy shock. With respect to environmental impacts, we are interested in what happens to the targeted pollutant, CO_2, as well as an important local air pollutant albeit nontargeted, PM-10. An abatement policy targeted at CO_2 has the unintended positive effect of reducing a local pollutant, PM-10.[3] We refer to this secondary reduction of PM-10 as an ancillary effect or ancillary benefit (Burtraw & Toman, 2000). It is well-established in the epidemiology literature the association between negative health effects and PM-10 exposure. The emissions of both pollutants are sector and process specific. Fairly disaggregated production activities and commodities accounts make this possible. Moreover, differed impact on households arising from environmental and trade policies can only be observed with multiple household types.

A brief summary of the findings is provided here. When considering the pollution-abatement policy alone, holding trade policy parameters constant, we observe that the cost in terms of growth is minor and that targeting one type of GHGs, CO_2, reduces the local air pollutant considered, PM-10. When assessing trade liberalization and its environmental implications, we find that the risk of specialization in dirty activity is modest but real for Thailand; the aggregate exports of polluting commodities rise by 4.27% with a drop of 0.09% in the aggregate exports of nonpolluting commodities. The overall carbon emissions rise only slightly by 0.12% compared to the benchmark with the 25% tariff reduction. This implies that with further trade liberalization, one can expect a large technological effect of substituting energy inputs with more nonenergy inputs and labor and capital across all sectors. When environmental and trade policies are combined, we see that they mitigate each other in terms of the negative effects: With further openness to the economy, we observe a smaller antigrowth effect than that under the environmental tax scenario. In addition, the target of a 20% reduction in carbon emissions is still met.

The Model

The model used in this article originates from the standard model built by the Trade and Macroeconomics Division of the International Food Policy Research Institute (Lofgren, Harris, Robinson, Thomas, & El-Said, 2001). It is calibrated to a 1998 Social Accounting Matrix (SAM), which is updated from the 1995 Input-Output table generated by the National Economic and Social Development Board to 1998 by the Thai

3. As well as other local pollutants such as SO_2 and NOx, but here we focus on PM-10 alone.

Development Research Institute (TDRI) of Thailand. Aside from the 1995 Input-Output table, which outlines the production structure of the commodity and activity accounts, TDRI drew from the following sources: the Thai National Account of 1998, which controls the aggregate values of final demands and national income; the current and capital account, which gives all external flows taking place in 1998; the 1998 household income and expenditure survey (Socioeconomic Survey), which is used to disaggregate households; and the employment and wages data from the 1998 Labor Force Survey. All data sources were reconciled to resolve the inconsistencies among them (see TDRI, 2000, for more details).

The 1998 SAM that this author obtained from TDRI was a slightly more aggregated version; it has 61 production sectors, 3 household categories (Agricultural, Nonagricultural, and Government Employed), and 3 factor types (1 labor and 2 capitals, agricultural capital and nonagricultural capital). A detailed list of the model dimensions is presented in Table 1. Unfortunately, detailed information on the labor force was not included in this SAM. As a result, only limited comments can be made about the distributional effects of various policy scenarios on different labor groups.

The following subsections briefly describe the main characteristics of the model.

Structure of the Economy

Traditionally, an agrarian nation, today Thailand, has a complex, multifaceted economy. Several important factors have contributed to Thailand's growth. Its principal comparative advantage has been the abundance and diversity of its natural resources. With its agrarian base as the bedrock, the economy has experienced steady growth. Today agricultural products are produced in such quantities that in the case of tapioca and rice, Thailand is the largest supplier in the world. It is also a leader in the production of frozen shrimp, canned pineapple, rubber, and sugar. Thailand's industrial sector produces a wide variety of goods ranging from textiles (including the well-known Thai silk and ready-made garments) to integrated circuits, plastics, footwear, and furniture. In recent years, manufacturing has surpassed agricultural products in Thailand's GNP, while tourism and the related service sectors have replaced agricultural products as Thailand's largest source of foreign exchange (Sunsite Thailand, n.d.). The country's rich minerals are also eagerly sought by the rest of the world. Tables 2 and 3 provide a more detailed look at the structure of the Thai economy.

Table 1
Dimensions of the 1998 Thailand

Activities or commodities (61)	
	Agricultural (7)[a]
	Energy-intensive manufacturing industries (15)[b]
	Other manufacturing industries (11)[c]
	Primary energy (8)[d]
	Transportation (5)[e]
	Services (15)[f]
Factors (3)	
	Labor
	Agricultural capital
	Nonagricultural capital
Institutions (7)	
	Households (agricultural, nonagricultural, and government employed)
	Private enterprises
	Public enterprises
	Government
	Rest of the world

Source: Li (2002b).
a. This category includes seven sectors: paddy rice, other crops, vegetables and fruit, livestock, fishing, and forestry.
b. This category includes 15 sectors: other mining, rice and flour, other agricultural products, beverages, textile, apparel, paper, basic chemical, plastic and rubber, nonmetal, basic metal, machinery, electric equipments, other industry, and construction.
c. This category includes 11 sectors: meat, canned foods, other food, tobacco, leather and footwear, wood products, furniture, printing and publishing, fabric metal, transport equipment, and water supply.
d. This category includes eight sectors: coal and lignite, liquefied petroleum gas, crude petroleum and natural gas, gasoline, diesel, aviation fuel, fuel oil, and electricity.
e. This category includes five sectors: land transportation, ocean transportation, inland water transportation, air transportation, and other transportation.
f. This category includes 15 sectors: hotel, restaurant, communications, insurance, banking, business services, education, nonprofit, recreation, personal services, health and medical services, and repairs.

PRODUCTION

The production function is a nested structure taking into account the optimizing behavior in the choice of production factors. It assumes constant returns to scale. Going from the top of the tree to the bottom, outputs from the three composite goods are aggregated via a constant elasticity of substitution (CES) technology: nonenergy intermediates, energy intermediates, and valued added. The nonenergy intermediate aggregate is obtained by combining all nonenergy commodities via a CES structure. The labor capital bundle is also aggregated via a CES

Table 2
Structure of the Thai Economy in 1998 (%)

Sector	*Output*	*Value Added*	*Final Demand*	*Exports*	*Imports*	*Export and Output*	*Import or Final Demand*
Agriculture	9.0	12.5	6.2	7.9	2.4	21.1	7.1
Primary energy	5.8	10.7	3.7	1.9	6.4	7.8	32.2
Energy-intensive industries	41.2	22.3	48.4	54.0	64.2	31.4	24.3
Energy-nonintensive industries	10.5	5.3	13.1	16.7	11.0	38.1	15.4
Transportation	6.4	6.7	6.1	5.1	3.6	19.3	10.6
Services	27.2	42.6	22.5	14.4	12.5	12.7	10.1
Total	100.0	100.0	100.0	100.0	100.0		

Source: Li (2002b).

Table 3
Distribution of Factor Incomes to Institutions (%)

		Capital	
	Labor	*Agricultural*	*Nonagricultural*
Household agricultural	13.9	58.7	3.6
Household nonagricultural	29.2	1.4	2.6
Household government employed	56.9	5.1	54.1
Public enterprises			5.5
Private enterprises		34.7	34.2
Total	100.0	100.0	100.0

Source: Li (2002b).

structure, allowing certain degrees of substitution among the factors. The energy composite is the CES aggregate of eight types of energy that are substitutable: coal and lignite, petroleum natural gas, gasoline, diesel, fuel oil, aviation fuel, liquefied petroleum gas, and electricity. Figure 1 depicts the nested decision process in the choice of production factors. The elasticities of substitution reflect the adjustment possibilities in producers' demand for production factors when the relative price of these factors changes. In this case, the default values were based on cross-country studies by Dessus and Bussolo (1998), among others. As part of the study, an upper and a lower bound values were used in the place of the assumed default for each of the CES elasticities to test the sensitivity of the main results to these alternative values. The higher and lower values were chosen based on the range of values observed for each elasticity in the literature. These alternative values are listed in Table 4. None of the alternative assumptions alters the basic findings of the study.

INCOME DISTRIBUTION AND ABSORPTION

Labor income is allocated to households according to a fixed coefficient distribution matrix derived from the original SAM. Likewise, capital revenues are distributed among the households, private and public enterprises, and the government. The relative incomes of the three households (agricultural, nonagricultural, and government employed) are of the following: On average, the government-employed household income is about 3.88 times that of agricultural household income and about 1.4 times higher than the income of nonagricultural household income. In other words, Thailand is made up of two relatively well-off households (government employed and nonagricultural) and one relatively poor household (agricultural).

On the consumption side, private consumption demand is obtained through maximization of household-specific utility function following

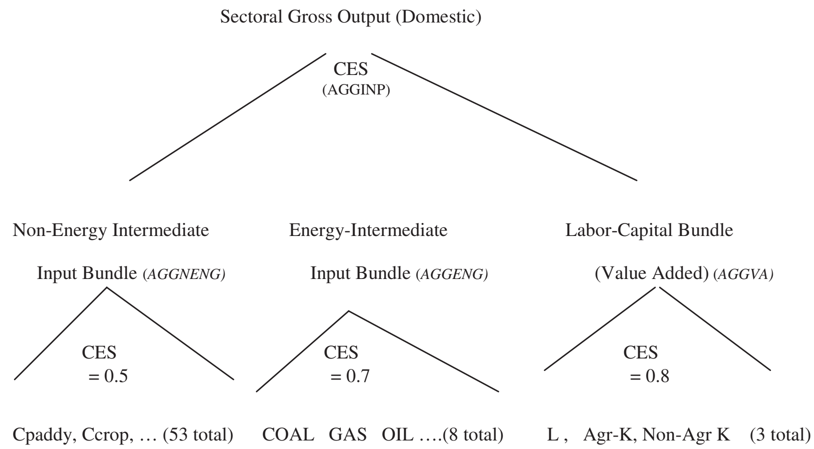

Figure 1: Nested CES Production
CES = constant elasticity of substitution; AGGINP = input elasticity for top level CES aggregation (or substitutability among aggregate energy input, aggregate nonenergy input, and aggregate value added); AGGNENG = input elasticity for nonenergy inputs (or substitutability among nonenergy intermediate inputs); AGGENG = input elasticity for energy inputs (or substitutability among energy inputs); AGGVA = input elasticity for value added (or substitutability between labor and capital); Cpuddy = paddy rice commodity; Ccrop = crop commodity; Agr-K = agricultural capital; Non-Agr K = nonagricultural capital.

Table 4
Default and Tested Values for CES parameters

	Default Values	*Lower Bound*	*Upper Bound*
AGGNENG	0.5	0.25	0.65
AGGENG	0.7	0.35	0.9
AGGVA	0.6	0.4	0.9
AGGINP	0.5	0.25	0.75

Source: Li (in press).
Note: CES = constant elasticity of substitution; AGGNENG = input elasticity for nonenergy inputs (or substitutability among nonenergy intermediate inputs); AGGVA = input elasticity for value added (or substitutability between labor and capital); AGGINP = input elasticity for top level CES aggregation (or substitutability among aggregate energy input, aggregate nonenergy input, and aggregate value added).

the Stone-Geary linear expenditure system or the extended linear expenditure system (Lluch, 1973). See Appendix A for the steps involved in deriving private consumption demand following the Stone-Geary linear expenditure system. Household utility is a function of consumption of different goods and saving. The household elasticities of consumption are different for each household and product, varying in the range of 0.40 (for basic products consumed) to 2.0 (for services). See Appendix B for the values.

The government consumption and the investment demands are disaggregated by sector with their shares determined using the data from SAM.

INTERNATIONAL TRADE

The model assumes imperfect substitution among goods originating from different geographical areas (Armington, 1969). Import demand is derived from a CES aggregation of domestic and imported goods. Export supply is symmetrically modeled as a constant elasticity of transformation function. Producers allocate their output to domestic or foreign markets in response to relative price changes. For Thailand, the Armington elasticities for demand between domestic and imported products are based on Warr (1998) and on the base-year shares of imports, exports, and two-way trade. The Armington elasticities for domestic versus export supply are obtained from Methakunavut and Jitsuchon (2001; see Appendix C for these values). The small-country assumption is applicable here, Thailand being unable to change world prices. This implies that the import and export prices are exogenous. The balance-of-payments equilibrium therefore determines the final value for the current account.

MODEL CLOSURE

The equilibrium condition on the balance of payments is combined with other closure conditions to solve the model. The model includes three macroeconomic balances: the (current) government balance, the external balance (the current account of the balance of payments, which includes the trade balance), and the savings-investment balance. The appropriate choice among the different macro closures obviously depends on the context of the analysis. Given that this is a single-period model, a closure combining fixed government consumption, fixed foreign savings, and fixed real investment is preferable for simulations that explore the equilibrium welfare changes of alternative policies (Lofgren et al., 2001).

With regard to government consumption, the model does not capture its direct and indirect welfare contributions. To avoid misleading results, it is preferable to keep government consumption fixed. For the government balance, we also set government savings at a fixed level and allow the direct tax rates of domestic institutions to adjust endogenously. The direct tax rates will be adjusted in a manner that would reflect their prepolicy rates paid by various institutions.[4]

For the external balance, the default closure[5] sets the real exchange rate flexible while foreign savings (the current account deficit) fixed. Given that all other items in the external balance (transfer between the rest of the world and domestic institutions) are fixed, the trade balance will also be fixed.

Total investment and total savings are set to equal, with savings originating from households, government, and the rest of the world. The closure used is investment driven, which means that the investment quantities are fixed. Under the chosen savings-investment closure, the investment is fixed and the savings rates of selected institutions are scaled so as to generate enough savings to finance investment.[6] Investment is one component of total absorption. The remaining components are household consumption and government consumption. With the nominal absorption shares of investment and government consumption fixed at base levels, the residual share for household consumption is also fixed.

EMISSIONS

Two types of polluting substances are considered: CO_2 and PM-10. An abatement policy targeted at CO_2 has the unintended positive effect of reducing a local pollutant, PM-10.[7] We refer to this secondary reduction of PM-10 as an ancillary effect or ancillary benefit (Burtraw & Toman, 2000). It is well established in the epidemiology literature the association between negative health effects and PM-10 exposure.

Industries that burn fossil fuels emit CO_2 as well as PM-10. Also, PM-10 is generated during what is called *process emissions* (as opposed to combustion emissions) in the case of cement and construction production where a great deal of dust is generated. Process emissions are not related to the amount of fuel used but are related to the total output produced. Another major source of PM-10 is vehicles or final consumption generated. When a carbon tax is imposed to induce less fossil fuel burning, we therefore do not expect the process-generated PM-10 to drop significantly, but we should expect the combustion-generated PM-10 (through industrial production and vehicular combustion through internal combustion engines) to drop more.

On the other hand, CO_2 emissions are emitted through combustion process only, both from industrial production and vehicle use.[8]

4. This is also known as government closure 3 or GOVCLOS-3 in the standard model.
5. This is also known as rest of world closure 1 or ROW-1 in the standard model.
6. This is also known as savings-investment closure 5 or SI-5 in the standard model.
7. As well as other local pollutants such as SO_2 and NOx, but here we focus on PM-10 alone.
8. Emission coefficients use in this study are available upon request.

The household utility functions do not include any term directly related to environmental quality. An emission-abatement policy will still have utility effects, however, through its effects on consumption and savings. Similarly, environmental degradation does not affect the productivity of production factors. Productivity gains resulting from a greener environment are not measured in this model. The potential gains from environmental protection policies are therefore most likely to be underestimated.

POLICY INSTRUMENTS

The model includes a variety of preexisting economic instruments: direct and indirect taxes on production or consumption, subsidies on production or consumption, and tariffs and other forms of taxes on imports. These taxes or subsidies are differentiated by sector, product, household, production factor, or consumption type. With respect to the instrument of a tax such as a uniform tax on each unit of polluting emission, the tax level can be endogenously determined if the level of emission abatement is targeted. An alternative is to exogenously set the tax to achieve targeted emission reduction. For the current article, the latter approach is adopted.

The Reference and Alternative Scenarios

We consider three basic scenarios in reference to the 1998 base year. The base year represents the reference or benchmark economic and environmental scenario in the absence of environmental, trade, or any other policy counterfactuals. The impacts of environmental and trade policies are then evaluated against this reference scenario by measuring the variations in the economic and environmental aggregates and the decomposed income distribution effects.

The first alternative scenario considers a targeted reduction of CO_2 emission. The target is set to reduce the overall CO_2 emissions level (production generated and consumption generated combined), with respect to the reference scenario by 20%. The instrument used to reach this target is a uniform tax on energy commodities (which are used as intermediate inputs and final consumer goods) per unit of emission. The second alternative scenario simulates a policy of unilateral trade liberalization through a reduction of import tariffs ad valorem by 25%. The third alternative scenario is a combined simulation of the two reforms.

Results

The aggregate economic and emission results are presented in Tables 5 to 8. The rows correspond to different scenarios, all relative to the benchmark level. In both of the cases involving a carbon tax, the carbon tax receipts are used or recycled to reduce income taxes on households and public enterprise at rates scaled to their prepolicy shock relative income tax burdens.

CARBON-ABATEMENT POLICY

The carbon-abatement policy examined appears to have minor costs in terms of output. The GDP is lowered by 0.60% with respect to the benchmark. Aside from the small negative effect on total output, the carbon tax policy also has a small negative impact on Thailand's terms of trade, with its aggregate exports dropping by 0.50% with respect to the benchmark.

A detailed analysis decomposing the various reduction effects would show a significantly lowered output for some of those sectors producing highly polluting goods[9] (up to 27% for the production of basic metals) and increased output levels in some of the nonpolluting sectors (composition effect). By aggregate sectoral categories, the sectors that contract the most are understandably the primary energy sectors and energy-intensive industries, with the total output of the former contracting by more than 15% and that of the latter around 1.8% (see Table 7). The result also shows that emissions abatement in the industries is obtained mostly through diminished pollution intensities (technology effect) by most sectors (energy intensive and nonenergy intensive), by substituting polluting energy intermediates with more labor and capital and to a lesser extent with nonenergy intermediates. For the simulations, labor and capital (agricultural and nonagricultural) are both assumed to be fully mobile. Capital is assumed fully mobile because of the medium- to long-term time frame for the static model runs; substitutability of capital for polluting intermediate inputs was allowed for the policy scenarios.

With respect to effects of the carbon tax on household income, we see a negative impact on the richest nonagricultural household (–3.38%), a slightly smaller impact on the government-employed households (–3.22%), and the smallest impact on the agricultural household (–1.80%). A more pronounced inequitable effect is observed in terms of

9. Highly polluting manufacturing consists of primary (7) and secondary (1) energy production, mining activities, paper production, basic chemical production, plastic and rubber production, nonmetal and basic metal productions, construction and trade activities, transportation activities (land, ocean, water, and air), the banking sector, health and medical service sector, and the public administration.

Table 5
Macroeconomic Effects by Scenario Relative to Benchmark (GDP and Trade)

	GDP (%)	*Total Exports (%)*	*Total Imports (%)*
Carbon tax policy only	–0.60	–0.50	–0.68
Tariff reduction policy only	+0.10	+2.38	+3.25
Combined tax and tariff policy	–0.44	+4.05	+5.54

Table 6
Emissions by Scenario Relative to Benchmark (Total CO_2 and PM-10)

	Total CO_2 (%)	*Total PM-10 (%; Ancillary Reduction)*
Carbon tax policy only	–20.0	–3.35
Tariff reduction policy only	+0.12	+0.42
Combined tax and tariff policy	–19.91	–2.95

consumption expenditures: A relatively small reduction is experienced by the richest, nonagricultural household (–1.13%), compared to the larger reduction experienced by the poorest agricultural household (–1.32%), and a consumption increase experienced by the second richest government-employed household (+1.23%).

Such an effect is witnessed in spite of the recycling of the carbon tax revenue to reduce income taxes. Revenue recycling was allowed to impact all three households (agricultural, nonagricultural, and government employed) and public enterprises through a reduction of their direct income tax by rates scaled to their initial income tax burden shares.

If equity is a concern, policy makers will need to contemplate additional ways that the burden can be equalized. One way to compensate the losers in this case is to recycle the carbon tax revenue for reducing only the income tax burden of the two lower income households. When this is done, the inequitable effects on consumption expenditures of the carbon tax policy no longer exist.

Under the carbon-abatement policy, with the 20% reduction of CO_2, there is an ancillary (unintended) benefit of reduced PM-10 by 3.35%. The reduction in CO_2 emission volumes is more because of decreased production-generated emissions (close to 20% reduction) than consumption-generated emissions (15% reduction). This can most certainly be attributed to the fact that most of the carbon tax burden is on enterprises, because these are the main polluters through their production activities.

Table 7
Trade Impact on Major Sectors Relative to Benchmark

	Exports			*Imports*		
	Energy Intensive (%)	*Energy Nonintensive (%)*	*Services (%)*	*Energy Intensive (%)*	*Energy Nonintensive (%)*	*Services (%)*
Carbon tax policy only	–0.35	+2.52	+7.29	–0.43	–0.89	–1.76
Tariff reduction policy only	+4.27	–0.09	–0.91	+4.00	+1.37	+0.50
Combined tax and tariff policy	+7.36	–0.17	+3.21	+7.22	+0.97	–0.69

Table 8
Welfare Distribution Relative to Benchmark (By Income and Consumption)

	Income			*Total Consumption*		
	Agricultural Households (%)	*Nonagricultural Households (%)*	*Government-Employed Households (%)*	*Agricultural Households (%)*	*Nonagricultural Households (%)*	*Government-Employed Households (%)*
Carbon tax policy only	–1.80	–3.38	–3.22	–1.32	–1.13	+1.23
Tariff reduction policy only	+0.18	+0.36	+0.41	+0.22	+0.23	+0.01
Combined tax and tariff policy	–2.04	+3.00	–2.92	–1.41	–0.65	+1.40

TRADE LIBERALIZATION

The trade policy scenario displays different results from the carbon tax scenario in the following ways: A 25% removal of trade barriers results in a moderate increase in more polluting activities, as opposed to less, compared to the benchmark. Highly polluting manufacturing sectors report minor growth rates as a share of total production (from 69.4% in the reference case to 70.3%), but a slightly higher growth in terms of share of exports (an increase from 71% to 74%). The 1.32% increase in production by the pollution-intensive sectors and the relative drop in the shares of production by the nonpollution-intensive sectors (–0.60% reduction by nonenergy intensive sectors and –0.40% by agricultural sectors) imply a slight composition shift (moving in the opposite direction of under the carbon tax policy scenario) that reflects the exploitation of Thai comparative advantage in polluting sectors. We do not observe a significant technology effect where producers use noticeably more nonenergy inputs and factors of production in the place of energy inputs except for a few service sectors. Instead, we observe a reduction in the use of all inputs (energy, nonenergy, and factors) in most sectors.

In terms of total emissions of CO_2, we observe a slight increase of 0.07% relative to the benchmark. This is consistent with the relative increase in pollution-intensive production and relatively less switch away from energy inputs compared to the carbon tax scenario. Concomitant with the rise in CO_2 is an increase in total PM-10 by 0.41%. Compared to the reductions under the carbon-abatement scenario (a 20% reduction in overall CO_2 and a 3.35% reduction in overall PM-10), the relative reduction of the two pollutants has changed, with PM-10 reduced by a higher percentage under the tariff-reduction scenario.

The final consumption and final output under the trade-policy scenario rise by 0.11% and 0.08%, respectively, compared to the benchmark. Trade liberalization results in a higher GDP (0.10% more) and in expanded volumes of trade (an additional 2.38% for exports and 3.25% for imports with respect to the benchmark levels in 1998). Trade liberalization has minor effects on final demand composition.

The income distribution effect is mildly inequitable under the trade-policy scenario, although income in all households rises slightly. The income of the poorest household (agricultural household) rises by only 0.18%, whereas it rises by 0.36% for nonagricultural households and 0.41% for the richest government-employed. Here, we do not have the option of recycling revenues from a tax to make the income distribution effects more equitable.

COMBINED REFORMS

The contrast between positive environmental results of pollution-abatement policies and economic gains of trade liberalization stimulates the study of a scenario where both emission taxes and tariff elimination are combined. This might also be a more realistic case than that of isolated policies. During the past 10 years, Thailand has been positioning itself to compete in a liberalized economy and has taken significant steps toward market liberalization. Thailand belongs to three trade groups: Asian Pacific Economic Community, Association of South-East Asian Nations (ASEAN), and the Cairnes Group (whose members are medium-sized exporters of agricultural goods; Food Market Exchange, 2001). A policy of trade liberalization with no associated measures of pollution control seems quite implausible for two reasons. First, a 25% tariff reduction appears to favor the more polluting sectors in Thailand. In addition, the PM-10 pollution or local air pollution worsens as a result of furthered trade liberalization. Therefore, antipollution demands could arise locally.[10] Antipollution pressures could also originate from Thailand's neighbor, whose terms of trade may deteriorate if Thailand's environmental regulation is relatively lax. The neighboring countries of Thailand or the rest of the ASEAN import a great deal from Thailand, with a heavy share of the imports being commodities from energy-intensive sectors (see Appendix D). These factors contribute to the conclusion that a combination of trade liberalization and abatement policy seems to be the most plausible scenario for Thailand.

The last row in Table 6 shows the emissions levels for the combined environmental and trade policies. The combination of environmental and trade policies leads to a reduction in carbon emissions close to that using the tax policy alone (19.91% as opposed to 20%), with a concomitant drop in local air pollutant PM-10 (–2.95%). Rather than composition effect, less emissions of CO_2 in this case is mainly the result of an economy-wide technology effect, where polluting intermediates are widely and significantly substituted with a great deal of labor and capital.

Combined reform leads to less GDP reduction compared to the GDP reduction under the tax policy alone (–0.44% as opposed to –0.60%). The lower economic loss is caused by the economic gains generated by a greater integration of the Thai economy into the international markets and the more efficient reallocation of factors as a result.

The welfare effects in this case, in terms of total consumption, however, are more inequitable than any previous scenarios. Again, this is in spite of recycling the carbon-tax revenues to reduce the income tax rates

10. The Thai economy has achieved a certain level of economic development, and its society has moved beyond caring about economy alone. Public health, for one, has gained greater emphasis, and the link between public health and air pollution has resulted in greater understanding.

after scaling by preexisting income tax rates. After adjusting the revenue-recycling shares so as to allow greater relative reductions in direct income taxes of the two lower income households, the regressive effects on consumption are reversed, and a slightly progressive effect on consumption compared to the benchmark scenario is generated.

CONCLUSION

The study supports several findings. Reducing trade tariff by 25% does have a modest but real risk of creating a Thai economy that is more specialized in producing dirty goods.

We also observe that environmental reforms through targeted fiscal policies on polluting goods (in either intermediate or final use) can achieve significant pollution abatement without much compromised GDP (only by 0.60%) or international competitiveness. The implementation of a carbon tax does not appear to harm Thailand's international competitiveness in any significant way. This result is consistent with the findings of several previous studies (Beghin, Roland-Holst, & van der Mensbrugghe, 1995; Bovenberg & Goulder, 1993; Dessus & Bussolo, 1998; European Economic Community, 1994).

When environmental reforms and trade liberalization are jointly implemented, the economic gains facilitated by greater trade can overcompensate for the negative economic effects of the environmental reforms, allowing the achievement of targeted emission reduction, while producing net economic growth. A proposition to coordinate the two kinds of policies could also reduce opposition to environmental abatement and render environmental abatement more politically feasible.

The inequitable impact of carbon tax and the combined policy reform on household consumption in this article was reversed via targeted revenue recycling. This highlights an important advantage of using a revenue-generating carbon abatement policy.

Finally, we need to emphasize several important qualifiers concerning our conclusions. First, in this article we do not incorporate growth effects of further trade liberalization (e.g., productivity increase). Therefore, the positive economic effects on output and welfare are in all likelihood underestimated. By more fully capturing these growth effects, the study results would be improved. Second, the model is country level and does not consider the economic and environmental impacts of the policies examined beyond the borders of Thailand. When the impacts of these Thailand-specific policies are evaluated at a regional or global level, the overall environmental and economic impacts may lead to different conclusions. Third, at the time of the study, certain emission coefficients specifically calculated for Thailand were not available. Applying Thailand-specific emission coefficients for all the emission calculation in the study would improve the quality of the study.

Appendix A
Consumption, Income Distribution, and Absorption

On the consumption side, private consumption demand is obtained through maximization of a household-specific utility function following the Stone-Geary linear expenditure system or the extended linear expenditure system (LES; Lluch, 1973). For each household, consumer demand, C, is defined by,

$$C_i = \gamma_i + \frac{\beta_i}{P_i}\left(Y - \sum_j P_j \gamma_j\right) \tag{1}$$

where Y is total nominal expenditure for the household, γ_i is the committed expenditures or "subsistence minima" in physical terms, P is the price per unit commodity consumed, and β_i is the marginal budget shares that determined the allocation of supernumerary income (i.e., the expenditure above that required for purchasing the subsistence minima; Dervis, de Melo, & Robinson, 1982). The parameters of LES are computed for each household using average budget shares from the Social Accounting Matrix, assumed income elasticities of demand, and a parameter measuring the elasticity of the marginal utility of income with respect to income (often called the "Frisch parameter"). In the LES, the Frisch parameter (ϕ) is equal to the ratio of total expenditure to supernumerary expenditure:

$$\theta = \frac{-Y}{Y - S} \tag{2}$$

where

$$S = \sum_j P_j \gamma_j \tag{3}$$

Given the average budget shares and expenditure elasticities, the marginal budget shares are given by

$$\beta_1 = \varepsilon_i \alpha_i \tag{4}$$

where ε_i is the expenditure elasticities and α_i is average budget shares. Note that the marginal budget shares must sum to 1, which is equivalent to imposing the condition, known as Engel aggregation, that the sum of the expenditure elasticities weighted by average budget shares must equal 1. This condition was met in determining household expenditure

(continued)

schedules (for three different types of household), using given budget share information. Informed by household expenditure elasticity schedule of cross-country studies, the schedule for Thailand was determined. The elasticity values, differentiated by household and product, vary in the range of 0.40 (for basic products consumed) to 2.0 (for services).

The subsistence minima γ_i is related to the other parameters according to the following equation:

$$\gamma_i = \left(\frac{Y}{P_i}\right)\left(\alpha_i + \frac{\beta_i}{\theta}\right) \tag{5}$$

The estimates of Frisch parameters were based on the range Dervis et al. (1982) reported based on a variety of cross-country studies. For countries with per capital GDP of about \$500, Dervis et al. found a range of Frisch parameter from –5.0 to –1.6 applied in the literature. For the country of Thailand, where the GDP per capita in 1998 was around \$1,300, –2 was chosen as the default value for the Frisch parameter; other values were considered in the sensitivity analysis.

Appendix B
Household Consumption Elasticities

Below are the assumed expenditure elasticities of market demand for various commodities by agricultural, government-employed, and non-agricultural households.

	HH-AGR	*HH-GOV*	*HH-NAG*
COCROP	0.5	0.5	0.4
CVGFRU	0.5	0.5	0.4
COAGR	0.5	0.5	0.4
CLIVSTK	0.5	0.5	0.4
CFISHIN	0.5	0.5	0.4
CFOREST	0.4	0.4	0.3
CRCEFLO	0.4	0.4	0.4
CMEAT	0.5	0.5	0.4
CCANFDS	0.4	0.4	0.4
COFOOD	0.5	0.5	0.4
COAGRPD	0.4	0.4	0.4
CBEVER	0.5	0.5	0.4
CTOBACO	0.5	0.5	0.4
CTEXTLE	1.25	1.2	1.1
CAPPARL	1.25	1.2	1.1
CLEAFOT	1.25	1.2	1.1

(continued)

	HH-AGR	HH-GOV	HH-NAG
CFURNIT	1.8	1.6	1.3
CPRNTPB	1.3	1.0	1.0
CGASLNE	1.8	1.6	1.1
CDEISEL	1.8	1.4	1.1
CELCMNU	1.8	1.6	1.3
CTRANEQ	2.0	1.7	1.6
COINDST	2.0	1.7	1.6
CELCITY	1.8	1.6	1.5
CLPGAS	1.8	1.6	1.2
CWATER	1.5	1.2	1.0
CTRADE	1.5	1.3	1.0
CRESTAU	2.0	1.6	1.2
CHOTEL	1.8	1.6	1.2
CTRANLD	1.4	1.3	1.0
CTRANWR	1.5	1.2	1.0
CTRANAR	2.0	1.8	1.3
CTRANOT	1.6	1.5	1.0
CCOMMUN	1.7	1.4	1.2
CBANKIG	1.0	1.0	1.0
CINSURE	1.0	1.0	1.0
CRESTAT	1.0	1.0	1.4
CBUSISR	1.0	1.0	1.0
CEDUCAT	1.1	1.0	1.0
CHLTHMD	1.1	1.0	1.5
CRCREAT	1.0	1.0	1.6
CRPAIRS	1.0	1.0	1.6
CPERSSR	1.0	1.0	1.6

Appendix C
Trade Elasticities

Sector	SIGMAQ	SIGMAT
CPADDY	1.1037	1.0
COCROP	0.6954	4.0
CVGFRU	1.6296	1.0
COAGR	1.5	5.0
CLIVSTK	1.0746	1.0
CFISHIN	1.5	1.0
CFOREST	0.3643	2.0
CCOALIG	0.3107	1.0
CPTRONG	0.2339	1.0
COMINE	0.3107	2.0
CRCEFLO	1.1037	1.0
CMEAT	1.6388	1.0

(continued)

Sector	*SIGMAQ*	*SIGMAT*
CCANFDS	1.6171	2.0
COFOOD	1.6171	2.0
COAGRPD	1.5	1.0
CBEVER	0.898	1.0
CTOBACO	3.4621	2.0
CTEXTLE	1.463	3.0
CAPPARL	1.5	4.0
CLEAFOT	1.0979	1.0
CWOODPR	0.9432	3.0
CFURNIT	0.9	2.0
CPAPER	0.9432	4.0
CPRNTPB	1.0182	4.0
CBASCHM	1.0339	3.0
CGASLNE	0.2339	2.0
CDEISEL	0.2339	2.0
CAVIFUL	0.2339	3.0
CFULOIL	0.2339	2.0
CPLASRB	1.2299	5.0
CNONMTL	0.5172	3.0
CBASMTL	0.8888	1.0
CFABMTL	0.7604	1.0
CMACHIN	1.2713	2.0
CELCMNU	0.9953	1.0
CTRANEQ	0.6	1.0
COINDST	1.3	3.0
CELCITY	0.8	1.0
CLPGAS	0.8	4.0
CWATER	0.8	1.0
CCONSTR	0.5	1.0
CTRADE	0.5	3.0
CRESTAU	0.8	2.0
CHOTEL	0.8	3.0
CTRANLD	0.8	1.0
CTRANOC	0.84	5.0
CTRANWR	0.84	4.0
CTRANAR	0.84	4.0
CTRANOT	0.84	1.0
CCOMMUN	0.84	1.0
CBANKIG	0.84	1.0
CINSURE	0.84	1.0
CRESTAT	0.84	1.0
CBUSISR	0.84	1.0
CPUBADM	0.84	1.0
CEDUCAT	0.84	1.0
CHLTHMD	0.84	3.0
CNONPRF	0.84	1.0

(continued)

Sector	*SIGMAQ*	*SIGMAT*
CRCREAT	0.84	1.0
CRPAIRS	0.84	1.0
CPERSSR	0.84	4.0

Source: Methakunavut & Jitsuchon (2001).
Note: SIGMAQ = the elasticity of substitution between imports and domestic output in domestic demand; SIGMAT = the elasticity of transformation for domestic marketed output between exports and domestic supplies.

Appendix D
Top 10 Imports of Thailand From ASEAN 1998 (million baht)

	Import in 1998	*Share in Total Import*
Electrical machinery and parts	47,969.3	18.1
Computer parts and accessories	32,414.3	12.2
Metal manufactures	23,339.9	8.8
Electronic integrated circuits	23,086.0	8.7
Chemicals	22,945.5	8.6
Cathode ray tubes	12,859.6	4.8
Industrial machinery	9,414.4	3.5
Electrical appliances	7,591.5	2.9
Crude oil	7,448.4	2.8
Lubricating oil and brake oil	7,414.5	2.8
Total of 10 items	194,483.5	73.2
Other Import	71,082.5	26.8
Total Import	265,566.0	100.0

Source: Ministry of Foreign Affairs (2000).

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