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Trade liberalization and the environment in Costa Rica

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ABSTRACT. This study examines the environmental impacts of trade liberalization in Costa Rica. A CGE model is constructed which includes eight environmental indicators covering deforestation, pesticides, overfishing, hazardous wastes, inorganic wastes, organic wastes, greenhouse gases, and air pollution. Three trade liberalization scenarios are examined. Two sets of analyses are conducted for each scenario, one in which technologies do not change in response to trade liberalization and the other in which total factor productivity in each sector changes in response to changes in imports of machinery and equipment. To account for uncertainty regarding values of the model's parameters, a Monte Carlo experiment is conducted for each policy option. The impacts of trade liberalization on the environmental indicators are generally negative in sign but small or moderate in magnitude, both when technology is constant and when technology is allowed to vary.

Introduction

Many developing countries have undertaken trade liberalization and other structural adjustment programs in recent years that have had significant impacts on economic activity. Because natural resource intensive sectors, such as agriculture, forestry, fishing, and mining, are usually a large part of the economies of developing countries, there has been much interest in recent years in the environmental impacts of these reforms (Munasinghe and Cruz, 1995). These countries typically do not have or only weakly enforce environmental protection laws. Indeed, macroeconomic, sectoral, and trade policies are often some of the few effective policy instruments available to policy makers in these countries. Governments in many developing countries cannot even deliver essential public services, to say nothing of effectively controlling the activities of producers or consumers. The complicated policy instruments often proposed to reduce pollution or

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promote 'sustainable development' are often beyond their institutional and administrative capabilities.

The objective of this study is to examine the environmental impacts of trade liberalization in the case of Costa Rica. To do this we construct a computable general equilibrium (CGE) model of the Costa Rican economy to analyze impacts on resource allocation and, as part of the model, eight environmental indicators. The indicators cover deforestation, pesticide usage, overfishing, hazardous wastes, non-hazardous inorganic wastes, non-hazardous organic wastes, greenhouse gases, and urban air pollution. Other researchers have used CGE models to examine the impacts of sectoral and macroeconomic policies on selected environmental indicators, such as CO_2 emissions and air pollution costs in Boyd, Krutilla, and Viscusi (1995), deforestation in Persson and Munasinghe (1995), and land use in Cruz and Repetto (1992). However, with the exception of Beghin, Roland-Holst, and van der Mensbrugghe (1998), who use a variety of indicators for water, air and soil effluents, this study is unique in the number and breadth of the indicators included.

Unlike most other studies of trade policy or other economic policies in developing countries, this study also permits technology to change in response to trade liberalization. These changes in technology, in turn, lead to changes in economic activity and the environmental indicators. As explained below, the principal effects of trade liberalization on technology in developing countries are likely to arise through imports of machinery and equipment embodying new technologies. In one set of analyses, we permit total factor productivity in each sector to change in response to changes in imports of machinery and equipment. The results from these analyses are compared with the results from analyses in which technology is held constant.

This study is also relatively unique in that it explicitly recognizes and models uncertainty regarding the values of the economic parameters in the model. Rather than picking one or a small number of sets of 'reasonable' parameter values, this study treats the economic parameters of the model as random variables drawn from prespecified distributions. Evaluation of each policy option takes the form of a Monte Carlo experiment in which a large number of random samples of the parameters are drawn, thereby generating an entire distribution of results rather than a single set of point estimates. This permits us to estimate standard errors for the changes in the mean values of the indicators, as well as to estimate the sample probability that an indicator worsens (in the sense that it increases). This information, in turn, permits us to assess the robustness of the results to different parameter values.

Costa Rica is a good case for study for at least four reasons. First, environmental problems in Costa Rica have been extensively studied. Compared to other developing countries, there is relatively good information on the types and magnitudes of environmental problems. Second, while natural resources are environmentally important in most developing countries, this is particularly true in Costa Rica. Costa Rica is among the richest ecological zones on earth, so that deforestation there entails greater threats to biodiversity than in most other parts of the world. Third, Costa

Rica is similar to many developing countries in the types of trade policy reforms implemented since the mid 1980s. Fourth, the Costa Rican economy is relatively small and uncomplicated, which facilitates CGE model formulation.

The CGE model

Our CGE model can be characterized as a single-country, static model of the type presented in Dervis, de Mello, and Robinson (1982) and Shoven and Whalley (1992), with modifications. The model contains 15 sectors, of which nine are based directly on the use of natural resources (bananas, coffee, sugarcane, grains, other crops, livestock and dairy, forestry, fishing, and electricity and water). Coffee and sugarcane include not only the actual production activities themselves but also the related processing activities. The other six sectors are food manufacturing, non-food manufacturing, petroleum refining, infrastructure, private services, and government services. The 15 'producer' goods from these sectors are combined in a manner described below to yield five 'consumer' goods purchased by Costa Rican households; food, durable goods, energy, health and education, and all other goods (AOG). Data for the 15 sectors are shown in Table 1. The equations of the model are laid out in an unpublished appendix that is available from the authors upon request.

The structure and parameters of the model are chosen from a medium-

Table 1. *Relative importance of sectors in the CGE model*

	Percentage of total for Costa Rican economy, 1985–1989					
Sector	*Gross output*	*Value added*	*Capital*	*Unskilled labor*	*Skilled labor*	*Farm land*
Bananas	2.8	3.7	1.3	3.2	0.9	0.9
Coffee	7.8	6.5	1.9	19.8	3.4	4.7
Sugarcane	1.6	1.5	1.1	2.2	1.0	1.9
Grains	1.0	1.5	0.4	7.9	0.7	7.8
Other crops	2.6	3.6	0.2	5.9	1.1	11.9
Livestock	7.2	5.6	2.8	6.4	3.3	72.7
Forestry	1.7	1.7	1.0	2.2	1.3	—
Fishing	0.5	0.7	0.3	1.7	0.3	—
Food manufacturing	7.1	3.5	2.9	2.0	3.1	—
Non-food manufacturing	16.5	9.8	8.0	8.7	11.0	—
Petroleum	2.5	1.0	1.2	0.0	0.2	—
Electricity and water	2.1	3.4	12.8	0.8	2.3	—
Infrastructure	9.8	9.0	14.5	10.7	7.7	—
Private services	26.1	32.3	31.2	23.3	35.5	—
Government services	10.5	16.1	20.4	5.2	28.3	—

Note: Columns may not add to 100 because of rounding.

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run perspective (on the order of five years or so). In general, CGE models are not good for short-term forecasting, which a static CGE model such as the one here does not capture the dynamic decisions that would be critical in a long-run analysis. A medium-run perspective is also more relevant for environmental policy-making purposes in developing countries than a long-run perspective. Evidence from a number of developing countries (see, e.g., Reed, 1992) indicates that policy makers tend, either implicitly or explicitly, to use relatively high discount rates in evaluating future environmental costs and benefits.

There are four primary factors of production: capital, unskilled labor, skilled labor, and land. Land is used in the six agricultural sectors (bananas, coffee, sugarcane, grains, other crops, and livestock and dairy) and in forestry. The quantity of land used in the forest sector is the total quantity of land in primary and secondary forests, excluding national parks and other protected areas. Land is a specific factor in the sense that it does not move between sectors and the quantity used in each sector is fixed. This is a reasonable assumption in the medium run, although clearly in the long run land may shift between uses. Simulations using a similar version of the model indicate that none of our quantitative results changes significantly when a plausible degree of intersectoral land mobility is introduced into the model and, more importantly, none of our broader conclusions changes at all (Abler, Rodríguez, and Shortle, 1995).

All 15 sectors use capital, unskilled labor, and skilled labor, with these factors being mobile between sectors. The economy's total supplies of capital, unskilled labor, and skilled labor are assumed to be fixed. Again, these are reasonable assumptions in the medium run, although in a long-run analysis these supplies would need to be endogenous.

The government has a variety of policies. It imposes ad valorem taxes on capital, unskilled labor, skilled labor, and land. It also imposes ad valorem output taxes on all producer goods except government services. As noted above, it taxes income from, and transfers income to, households. It receives a small amount of net transfers from abroad in the form of foreign aid, which are assumed to be a given fraction of other government revenue. In addition, it levies ad valorem import tariffs, imposes ad valorem export taxes in some sectors, and provides ad valorem export subsidies in other sectors. A fixed fraction of total government expenditures is devoted to purchases of government services. Revenue remaining after transfers and purchases of government services is saved.

The CGE model is calibrated to a social accounting matrix (SAM) developed by Rodríguez (1994) using data for Costa Rica for 1985–9, the model's base period. A SAM is an accounting framework designed to show all transactions that occur among all actors in an economy during a given time period. The Costa Rican economy is somewhat different today than it was during 1985–9—for example, tourism, banking, real estate, and high-technology industries have grown substantially in importance since the late 1980s. However, to our knowledge, there are no SAMs currently available for Costa Rica for the mid or late 1990s that would incorporate these changes.

Technical change in response to trade liberalization

Trade can have many effects on technical change (Grossman and Helpman, 1991). For example, by enlarging potential markets, trade can enable firms to better exploit scale economies in research and development (R&D). Many innovations are characterized by substantial up-front R&D costs, followed by production costs that are small or trivial in comparison with R&D costs. Trade can also lead countries to specialize in the generation of innovations, thereby avoiding inefficient duplication of efforts. On the other hand, a country with a comparative disadvantage in R&D might find that trade induces factors of production to move out of R&D altogether.

In addition, by changing relative output prices, trade alters the incentives to do research in one sector versus another because the rate of return to output-increasing R&D depends positively on output prices. Moreover, changes in relative output prices can have Stolper–Samuelson effects on factor prices. An increase in the relative output price in a sector tends to increase the relative prices of factors in which that sector is relatively intensive and decrease the relative prices of other factors. These changes in factor prices can in turn lead to changes in technologies along the lines predicted by the induced innovation model (Hayami and Ruttan, 1985). In the induced innovation model, technologies are developed and adopted which conserve on relatively expensive factors of production.

For developing countries, however, the main issue with respect to technology is generally not development but adoption. As Coe, Helpman, and Hoffmaister (1997) emphasize, over 95 per cent of global R&D is done in developed countries. Thus, for developing countries, the challenge is to take advantage of technologies invented elsewhere. Trade may facilitate this process because it enables a country to purchase a larger variety of capital equipment and intermediate inputs embodying technologies not previously available. These technologies can potentially include so-called 'environmentally friendly' or 'clean' technologies (Low, 1992). Trade may also provide channels of communication through which producers can learn about, and then copy or adapt, technologies used in other countries. Coe and Helpman (1995) and Coe, Helpman, and Hoffmaister (1997) find that spillovers in research and development (R&D) between countries are significant, and that they are stronger the more open an economy is to trade.

Coe, Helpman, and Hoffmaister (1997) estimate that the elasticity of economy-wide total factor productivity (TFP) in developing countries with respect to imports of machinery and equipment is about 0.02, with a 95 per cent confidence interval of approximately (0.01, 0.03). These results are quite robust to alternative specifications of their econometric model.

The task here is to apportion an economy-wide TFP change among our 15 sectors. Because trade-induced spillovers in technology operate primarily through capital goods, one simple and plausible option is to model the change in each sector's TFP as proportional to its initial share of the economy's total capital stock

$$\hat{A}_i = s_i \delta_i \hat{M} / \textstyle\sum_j s_j^2,$$

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where $\hat{A}_i$ is the percentage change in TFP in sector i (i = 1,...,15), s_i is the initial share of the total capital stock (so that $\Sigma_i s_i = 1$), δ_i is the elasticity of TFP with respect of machinery and equipment imports, and $\hat{M}$ is the percentage change in machinery and equipment imports. The s_i are shown in percentage terms in Table 1. As explained below, the δ_i are assumed to be uniformly distributed random variables. Based on the results by Coe, Helpman, and Hoffmaister (1997), the minimum and maximum for each δ_i are set at 0.01 and 0.03, respectively, so that the mean in each case is 0.02. Given this, the expected value of the economy-wide, capital share-weighted average of the $\hat{A}_i$ is also 0.02

$$\hat{A} \equiv E\,(\Sigma_i s_i \hat{A}_i) = [\Sigma_i s_i^2 E(\delta_i)]\hat{M} / \Sigma_j s_j^2 = 0.02\hat{M}.$$

There is no separate machinery and equipment sector in the CGE model. However, $\hat{M}$ can be well approximated by the percentage change in imports of non-food manufactured products.

Modeling parameter uncertainty

In any simulation exercise, uncertainty about parameter values can be a major limitation. In most cases, there are no econometric estimates of the majority of model parameters or at least estimates specific to the country being studied. In those rare cases where there are many estimates of a particular parameter, it can still be difficult to choose an appropriate value because the estimates often differ dramatically. The usual procedure is to pick one or two sets of 'reasonable' parameter values and possibly investigate the sensitivity of a model to different parameter values by varying one parameter at a time, while keeping all other parameters at their base values. This approach ignores the possibility that two or more parameters could act in combination to yield unusual or unexpected results. Significant declines in computing costs in recent years make it feasible to account for uncertainty in a more systematic manner,

In order to address parameter uncertainty, we assume that all the substitution elasticities in production, base-period own-price and income elasticities of consumer demand (with the exception of the income elasticity of demand for all other goods, or AOG), elasticities of import supply, elasticities of export demand, and elasticities of TFP with respect to non-food manufacturing imports are random variables. The income elasticity of demand for AOG is an exception because it is residually determined from the other consumer income and price elasticities of demand and the initial consumer budget shares in order to satisfy the adding up constraint on consumer demands. Evaluation of each of the policy options described below takes the form of a Monte Carlo experiment.

Each elasticity is assumed to follow a univariate uniform distribution. This distribution is a reasonable way to model a range of values for each parameter viewed as plausible on a priori grounds. Upper and lower bounds for each elasticity were chosen on the basis of econometric studies of Costa Rica (where available), econometric studies of other developing countries, and our own intuition regarding plausible parameter values from a medium-run perspective.[1]

The procedure used here for choosing the sample size of each Monte Carlo experiment is described in Abler, Rodríguez, and Shortle (forthcoming). The procedure is designed to limit the margins of error in estimating the changes in the environmental indicators. In our case here, the sample size of each Monte Carlo experiment is set at 10,000. This can be shown to be sufficient to achieve, with a 95 per cent probability, an upper limit of 0.1 percentage points on the margin of error in the estimated percentage change in every environmental indicator. Abler, Rodríguez, and Shortle (forthcoming) discuss the advantages of the Monte Carlo procedure relative to other procedures that have been proposed in the literature for dealing with parameter uncertainty in economic models.

The environmental indicators

We use eight environmental indicators in order to gain insight into the potential impacts of trade liberalization on environmental pressures. The indicators are: gross primary and secondary deforestation; pesticide usage in agricultural production; gross deletion of the stock of fish and other aquatic life in the Gulf of Nicoya; solid and liquid hazardous wastes; solid inorganic wastes (excluding hazardous wastes); solid organic wastes from coffee and banana production and processing; gross greenhouse gas emissions; and anthropogenic air pollution in the metropolitan San José area. These indicators were chosen on the basis of key environmental problems identified in Costa Rica's National Environmental Action Plan (MIDEPLAN, 1996) and data availability. They also fall within the environmental priority areas for developing countries generally outlined by the World Bank (1992).

Each indicator is assumed to be a linear function of variables in the CGE model. The linearity assumption is common in the literature (e.g., Boyd, Krutilla, and Viscusi 1995; Vennemo, 1997) and, in a setting with limited environmental information, it is hard to argue in favor of more complicated alternatives. Moreover, the changes considered here in the variables contributing to each indicator are on the whole small, so that any approximation errors due to the linearity assumption should also be small.

Each indicator E_k ($k = 1,...,8$) is defined as

$$E_k = E_k^0 \sum_{j=1}^{J_k} \omega_{kj} \mathrm{V}_{kj} / \mathrm{V}_{kj}^0 .$$

Where E_k^0 is the base-period (1985–9) value of E_k, V_{kj} is the jth variable ($j = 1,...J_k$) to which the kth indicator is linked, V_{kj}^0 is its base-period value, and ω_{kj} is the weight attached to V_{kj} ($\omega_{kj} > 0$, $\Sigma_j \omega_{kj} = 1$). Table 2 lists the variable(s) to which each indicator is linked. Table 2 also shows, in percentage terms, the weight attached to each variable. For the purposes of calculating the results below, each indicator is expressed in the form of a percentage change from its base-period value, or $100(E_k/E_k^0 - 1)$.

Deforestation has historically been the most serious environmental and

[1] An unpublished table listing the upper and lower bounds is available from the authors upon request.

Table 2. *The environmental indicators*

Indicator	*Base-period level (per year)*	*Cause(s)*	*Corresponding variable(s) n Model (V_{kj})*	*Weight attached to each variable (ω_{kj})(%)*
Deforestation (1000 ha)	64.3	Forestry	Forestry output	100
Erosion (1000 mt)	225	Bananas	Land (75%) & Capital (25%), Bananas	1
		Coffee	Same (Coffee)	3
		Sugarcane	Same (sugarcane)	1
		Grains	Same (grains)	24
		Other crops	Same (other crops)	37
		Livestock	Same (livestock)	35
Pesticides (1000 mt)	3.8	Bananas	Non-food manufactured Intermediate Inputs, Bananas	26
		Coffee	Same (coffee)	18
		Sugarcane	Same (sugarcane)	5
		Grains	(Same (grains)	34
		Other crops	Same (other crops)	16
Overfishing (Millions 1987 colones)	850	Fishing	Fishery output	100
Hazardous wastes (1000 mt)	18.6	Manufacturing	Intermediate input aggregate, non-food	60
		Hospital wastes	manufacturing Household health & Education consumption	19
		Households	Household AOG	21
Inorganic wastes (1000 mt)	592	Households	consumption Total household consumption expenditures	97
		Manufacturing	Intermediate input aggregate, non-food manufacturing	2
		Bananas	Non-food manufactured Intermediate inputs,	1
Organic Wastes (1000 mt)	3688	Bananas	bananas Banana output	84
		Coffee	Coffee output	16
Greenhouse gases (Million mt CO_2 equivalents)	16.2	Fossil fuels	Total petroleum use	17
		Wet rice	Grain output	3
		Livestock	Livestock output	44
Deforestation			Forestry output	25
		Manufacturing	Non-food manufacturing output	2
		Household wastes	Total household consumption expenditures	8
Air pollution (µg/m^3 TSP equivalents)	290	Fossil fuels	Total petroleum use	100

Note: ha = hectares, mt = metric tons, AOG = all other goods, and TSP = total suspended particulates. Percentages may not add to 100 because of rounding.

natural resource issuing facing Costa Rica. There have been several conflicting estimates of deforestation in Costa Rica using different methodologies (Rodríguez, 1994). However, they all agree that forest cover has fallen from over three-fourths of the total area at the turn of the century to less than one-third today, and that the most rapid rate of deforestation has occurred since the 1960s. Historically, deforestation was motivated primarily not by a desire to harvest timber but rather by a desire to covert forests to pasture and, to a lesser degree, crop land (Solórzano *et al*., 1991). However, timber harvesting is probably now the predominant force behind deforestation because most of the remaining forest land would be of marginal value as agricultural land (Lutz *et al*., 1993). Data for the deforestation indicator are from Solórzano *et al*. (1991).

As is the case in many countries, significant depletion has occurred in the stocks (and harvests) of many species of fish in Costa Rica. The overfishing indicator is for the Gulf of Nicoya because this is where the greatest depletion has occurred. Indeed, the Gulf of Nicoya is a textbook case of the resource depletion problems that tend to occur with open access resources. Data for the overfishing indicator are from Solórzano *et al*. (1991).

A number of large fish kills, several longer-term threats to flora and fauna, and threats to drinking water supplies have been linked to pesticide use (Castillo, 1995; Thrupp, 1988). Pesticides have also become a high-profile issue in Costa Rica because of the relatively high frequency of acute poisonings and chronic health problems among farm workers and formulators, particularly in banana production. There have been some efforts in recent years to reduce pesticide usage in banana production, but on the whole it is still quite pesticide intensive. Data for the pesticides indicator are from Castillo (1995).

Relative to many other countries, the quantity of hazardous wastes generated in Costa Rica is not large. On an annual basis, the base-period (1985–9) quantity was about 0.3 mt/km^2 and only about 0.005 mt/person (GTZ, 1991). By comparison, the corresponding figures for the US were nearly 30 mt/km^2 and more than 1 mt/person (World Resources Institute, 1990). However, unlike the US and most other developed countries, the majority of hazardous wastes in Costa Rica are not treated, and insufficient attention is paid to siting and disposal issues (MIDEPLAN, 1996). Data for our hazardous wastes indicator are drawn from GTZ (1991).

Inorganic wastes, which consist almost entirely of household solid wastes, are often disposed of in ways that are unsafe or unsightly (MIDEPLAN, 1996). In addition, there have been serious political problems in identifying new municipal waste disposal sites. The bulk of our organic wastes indicator is due to residues from banana production, with the remainder consisting of residues from coffee processing. Banana production is concentrated in the eastern part of the country, while coffee processing is concentrated in the Central Valley. In both cases, residues are typically dumped directly into rivers and streams, where they can degrade aquatic habitats, lead to insect infestations, and cause a proliferation of algae and lilies in reservoirs used for hydroelectric power generation. Some Costa Rican coffee processors have taken steps to reduce effluents from coffee processing in recent years, but most have not done so. For the purposes of calculating these two indicators, only non-hazardous wastes are included since we already have a hazardous wastes indicator. Data are from GTZ (1991).

Health-based ambient concentration standards for a number of pollutants are often exceeded in San José and other urban areas (Gutiérrez Espeleta *et al*., 1995; Del Rosario Alfaro, 1995). Over two-thirds of urban air pollution is generated by transportation, while virtually all the remainder are due to other petroleum-using activities. With almost all electric power generated by hydroelectric plants and little heavy industry, Costa Rica does not have a major problem with stationary sources. The air pollution indicator is a health-weighted sum of pollution from total suspended particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2). The weights, which are extremely rough, are based on Lipfert (1994). Data on the pollutants themselves are from Instituto Meteorológico Nacional (1995) and Gutiérrez Espeleta *et al*. (1995). It may be noted that, since the only contributor to the indicator is total petroleum use, the percentage change in the indicator in response to a policy change is independent of the weights assigned to the various pollutants.

Greenhouse gases are often correlated with other air pollutants that have adverse health effects, while some greenhouse gases can directly threaten human health. Greenhouse gas emissions also reduce Costa Rica's potential to earn revenue as a greenhouse gas sink. Electric utilities in the US have the option of meeting greenhouse gas emission standards by locating offsetting sinks in other countries, and one such country is Costa Rica. Costa Rica is such a small country that its greenhouse gas emissions and sequestration do not have significant implications for the global climate. However, our greenhouse gas indicator may be useful in suggesting ranges of possible responses to economic policy reforms in developing countries as a whole, which when taken together have a significant influence on global greenhouse gas emissions. To compute the greenhouse gas indicator, greenhouse gases were converted to carbon dioxide (CO_2) equivalents using global warming potential (GWP) coefficients given a time horizon of 20 years. Data on greenhouse gas emissions are from Instituto Meteorológico Nacional (1995).

The deforestation, overfishing, and greenhouse gas indicators are gross measures rather than net measures: reforestation, natural regeneration of the population of fish and other aquatic life, and carbon sequestration by existing forests or reforestation are not included. The net measures are the preferred ones on theoretical grounds. However, it is not possible within the confines of a static CGE model to model dynamic processes such as reforestation, fish population regeneration, or forest growth. One could still 'construct' a net measure of deforestation, for example, by assuming an exogenous level of reforestation, but this would be highly artificial.

For purposes of comparison, however, we did calculate net indicators assuming a constant level of resource regeneration. The results for the net overfishing and net greenhouse gas indicators were fairly close to their gross counterparts because estimated base-period resource regeneration levels were small. In the case of overfishing in the Gulf of Nicoya, data in Solórzano *et al*. (1991) suggest an annual regeneration of about 50 million coones versus an annual gross depletion of about 850 million colones. For greenhouse gases, data from Instituto Meteorológico Nacional (1995) suggest an annual carbon sequestration of about 1.6 million metric tons (mt) versus annual gross emissions of about 16.2 million mt. However, in the case of deforestation, data of reforestation in Solórzano *et al*. (1991) suggest that net deforestation in the late 1980s was about zero, so that changes on a percentage basis in the net indicator would obviously be much larger than changes in the gross indicator.

It should be noted that all eight indicators measure environmental pressures rather than the actual state of the environment or the social costs of environmental degradation. In percentage terms, changes in the social costs of environmental degradation could be larger or smaller than changes in the environmental indicators. For instance, if deforestation is now occurring in more ecologically sensitive or important areas than it has in the past, a 1 per cent increase in deforestation will lead to a greater than 1 per cent increase in the social costs of deforestation. On the other hand, if organic wastes are being dumped into rivers that are already essentially dead because of past pollution, then the social cost of 1 per cent increase in organic wastes will be less than 1 per cent. Unfortunately, we lack information that would allow us to reliably estimate social costs of changes in the environmental indicators.

It should also be noted that, while the model permits economic activity to affect the environment, there are no feedback effects from the environment to the economy. Feedback effects could arise through changes over time in the economy's supplies of land, forests, aquatic life and other natural resources, changes in input productivity, and changes in human health (World Bank, 1992; Vennemo, 1997).

Trade policy scenarios

Prior to 1986, Costa Rican trade policy was characterized by import substitution. Import tariffs were defined by the Common Central American Tariff (ACC) and the Central American Agreement on Fiscal Incentives (CCIF). The ACC consisted of three import taxes: an ad valorem tax, a specific tax with the rate dependent on the type of good, and a tax on 30 per cent on the sum of the first two taxes. The CCIF provided exemptions, which in some cases were complete, for imported raw materials, imported capital goods, and other imported inputs. Since 1986, import tariff rates have been reduced as part of structural adjustment and trade liberalization programs.

Costa Rica entered the General Agreement on Tariffs and Trade (GATT) in 1990, but without signing the GATT Subsidy Code. This means that Costa Rica's current export subsidies are not subject to compensatory tariffs in the immediate future, at least by GATT members. Since the early 1970s, export subsidies of up to 30 per cent over the FOB value have been used to promote exports of some manufactured goods and other 'non-traditional' exports. However, steps have been taken in recent years to reduce export subsidies. Membership of GATT was a major step forward freer trade and a radical departure from the protectionist policies that had been followed since the 1950s. Base-period export and import tax rates are shown in Table 3.

Three trade policy scenarios are investigated here. In the first policy scenario, ad valorem rates for tariffs are limited to 5 per cent. Tariffs at or below that rate are unchanged. This change affects fishing, food manufac-

Table 3. *Base-period trade and trade policy*

	Trade, 1985–1989		*Trade policy, 1985–1989*	
Sector	*Exports as a percentage of gross output*	*Imports as a percentage of total consumption*	*Export tax rate (per cent)*	*Import tariff rate (per cent)*
Bananas	88	0	8.7	—
Coffee	53	0	11.0	—
Sugarcane	27	0	11.1	—
Grains	0	18	—	5.0
Other crops	39	34	−9.1	5.0
Livestock	18	5	5.6	5.0
Forestry	13	8	−9.1	5.0
Fishing	40	3	−9.0	10.7
Food manufacturing	11	9	−10.6	10.0
Non-food manufacturing	34	57	−2.3	12.0
Petroleum	5	33	0	0
Electricity and water	0	2	—	0
Infrastructure	12	0	0	—
Private services	2	6	0	0
Government services	0	0	—	—

Note: Total consumption is the sum of household consumption, government consumption, investment demands, and intermediate demands.

tures, and non-food manufactures. Tariffs are cut by half or more in these sectors, which is significant because manufactured goods constitute the vast majority of total imports. This scenario corresponds to Costa Rica's current GATT obligations. In the second policy scenario, export subsidies are also limited to 5 per cent. This represents about a 50 per cent cut in the export subsidy rate for other crops, forestry, fishing, and food manufactures. The third policy scenario has the fewest trade distortions. In this case, import tariffs, export taxes, and export subsidies are all limited to 5 per cent. The cut in export taxes works to the benefit of bananas, coffee, sugarcane, and (to a minor extent) livestock.

All three trade policy scenarios involve liberalization of commodity trade. However, like many other developing countries, Costa Rica is also now more open to foreign direct investment than in the past. It would be interesting to examine the environmental impacts of capital market liberalization, but that is beyond the scope of this paper.

Results and discussion

The impacts of trade liberalization on the environmental indicators when technology is held constant are shown in Table 4. The corresponding impacts when total factor productivity is allowed to vary in response to trade liberalization are shown in Table 5. These tables show the mean percentage change in each indicator across the 10,000 random samples, the standard deviation (in parentheses), and the sample probability that each indicator worsens, in the sense that it increases [in brackets]. The standard deviations tend to be quite small in absolute terms and relative to the

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Table 4. *Environmental impacts of trade liberalization (technology constant)*

Indicator	*Tariffs ≤ 5% (first scenario)*	*Tariffs & export subsidies ≤ 5% (second scenario)*	*Tariffs, export subsidies, & export taxes ≤ 5% (third scenario)*
Deforestation	3.3	1.9	1.8
	(1.0)	(0.7)	(0.8)
	[1.00]	[1.00]	[1.00]
Pesticides	6.9	5.4	8.9
	(1.3)	(1.1)	(1.7)
	[1.00]	[1.00]	[1.00]
Overfishing	8.5	−1.6	−4.1
	(2.6)	(1.0)	(1.5)
	[1.00]	[0.05]	[0.00]
Hazardous wastes	–7.4	–4.9	–9.2
	(1.8)	(1.7)	(2.8)
	[0.00]	[0.00]	[0.00]
Inorganic wastes	–0.4	–0.3	–0.5
	(0.1)	(0.1)	(0.3)
	[0.01]	[0.02]	[0.07]
Organic wastes	4.4	4.6	10.0
	(1.6)	(1.7)	(3.5)
	[1.00]	[1.00]	[1.00]
Greenhouse gases	2.2	1.9	1.5
	(0.4)	(0.4)	(0.5)
	[1.00]	[1.00]	[1.00]
Air pollution	2.4	2.3	2.1
	(0.4)	(0.4)	(0.5)
	[1.00]	[1.00]	[1.00]

Note: The top figure in each cell is the mean percentage change in the indicator. The figure in parenthesis is the standard deviation of the percentage change, while the figure in brackets is the sample probability that the indicator worsens.

means, suggesting that the results are fairly robust to different parameter values. Moreover, the sample probability that an indicator worsens is either zero or one in the vast majority of cases, indicating that the signs of the changes in the indicators are also robust to different parameter values.

On average, trade policy changes with technology held constant lead to moderate decreases in the quantity of hazardous wastes and small or moderate increases in most other environmental indicators. The reason for the decline in hazardous wastes is that about 60 per cent of hazardous wastes are generated by the non-food manufacturing sector, which shrinks in response to trade liberalization. As capital, unskilled labor, and skilled labor move out of non-food manufacturing and into other sectors, environmental pressures associated with those sectors increase.

The two indicators that show the largest increases are pesticides and organic wastes. Pesticide usage increases mainly in response to expanded banana, coffee, and sugarcane production, while banana and coffee production drive the increases in organic wastes. Among the three trade

Table 5. *Environmental impacts of trade liberalization (technology variable)*

Indicator	*Tariffs ≤ 5% (first scenario)*	*Tariffs & export subsidies ≤ 5% (second scenario)*	*Tariffs, export subsidies, & export taxes ≤ 5% (third scenario)*
Deforestation	3.4	2.0	1.9
	(1.0)	(0.7)	(0.8)
	[1.00]	[1.00]	[1.00]
Pesticides	6.0	4.6	7.9
	(1.2)	(1.1)	(1.6)
	[1.00]	[1.00]	[1.00]
Overfishing	6.9	–2.9	–5.4
	(2.2)	(1.1)	(1.7)
	[1.00]	[0.00]	[0.00]
Hazardous wastes	–0.6	1.5	–2.4
	(2.4)	(2.4)	(3.1)
	[0.40]	[0.72]	[0.22]
Inorganic wastes	1.2	1.2	1.1
	(0.4)	(0.4)	(0.5)
	[1.00]	[1.00]	[1.00]
Organic wastes	3.8	4.0	9.3
	(1.4)	(1.4)	(3.1)
	[1.00]	[1.00]	[1.00]
Greenhouse gases	2.6	2.3	2.0
	(0.4)	(0.4)	(0.5)
	[1.00]	[1.00]	[1.00]
Air pollution	3.5	3.3	3.2
	(0.5)	(0.5)	(0.6)
	[1.00]	[1.00]	[1.00]

Note: The top figure in each cell is the mean percentage change in the indicator. The figure in parenthesis is the standard deviation of the percentage change, while the figure in brackets is the sample probability that the indicator worsens.

policy scenarios, the mean increases in pesticide usage and organic wastes are largest in the scenario with the most complete liberalization. This is because bananas, coffee, and sugarcane and the three sectors most disadvantaged by base-period trade policy.

In contrast, while gross deforestation increases in all three trade liberalization scenarios, the mean increase becomes smaller as the degree of liberalization increases. Relative to the first scenario, sectors other than forestry become more attractive in the second and third scenarios because forestry's export subsidy rate is cut. The mean change in the overfishing indicator reverses signs as the degree of trade liberalization increases, being positive in the first scenario and negative in the second and third scenarios. This can be attributed to the cut in the fishery sector's export subsidy rate in the latter two scenarios.

In general, the results for the technology-constant case do not change substantially when technology is allowed to vary. However, there are differences, with the most important difference involving hazardous wastes.

Hazardous wastes fall moderately in all three scenarios given constant technology. When technology is variable, however, only small decreases in hazardous wastes occur in the first and third trade policy scenarios, while a small increase actually occurs in the second scenario. The reason is that non-food manufacturing, which as noted above accounts for the majority of hazardous wastes, is also a relatively capital-intensive sector. As such, it benefits more than most other sectors from new technologies embodied in imported machinery and equipment.

In the case where technology is allowed to vary, the increase in the capital-share weighted average of TFP across sectors is only about 0.8 per cent in all three scenarios. Among sectors, the largest increase in TFP, about 1.3–1.4 per cent occurs in the private services sector. This sector accounts for over 30 per cent of the economy's base-period capital stock (see Table 1). The relatively small increases in TFP explain why the differences between the technology-constant and technology-variable results for the environmental indicators are generally small.

As a caveat, the type of technical change considered here—an increase in productivity that has no impact on emissions of pollutants per unit of output—is not the only possible type of technical change in response to trade liberalization. As noted earlier, one common argument in favor of trade is that it can encourage the flow of so-called 'clean' technologies from developed countries to developing countries (Low, 1992). A clean technology could reduce total emissions of a pollutant even if output increased, provided the decrease in emissions per unit of output was sufficiently large. If trade did lead to an inflow of clean technologies, the small increases in most of the environmental indicators found here would be smaller or perhaps change sign. The decreases in some of the indicators could be even larger.

Conclusions

The results here for Costa Rica do not necessarily generalize to other countries. Costa Rica's trade regime prior to reforms initiated in 1986 was protectionist, although by no means as protectionist as many other developing countries. The environmental impacts of trade liberalization might be greater in a country with greater preexisting trade distortions, particularly when changes in technology in response to trade liberalization are taken into account. Furthermore, Costa Rica itself has changed in many ways noted above since the model's base period of 1985–9.

Bearing this is mind, four major conclusions emerge from our results. First, the directions of environmental impacts of the trade liberalization scenarios considered here are generally negative. In the third scenario, which involves the greatest degree of liberalization among the scenarios considered, five or the eight environmental indicators worsen in the case where technology is constant. In the case where technology is variable, six of the eight indicators worsen in this scenario.

Second, even though the directions of impacts are generally negative, the magnitudes of impacts tend to be small relative to the base-period values of the environmental indicators, in the sense that most indicators change by less than 5 per cent. The two exceptions are pesticides and organic wastes, where moderate increases (between 5 per cent and 10 per cent) in environmental pressures occur in some scenarios. We take this to mean that the economic benefits of trade liberalization should not be sacrificed for the sake of protecting the environment. Instead, the results suggest review and possible enhancement of environmental policies targeted at pesticides and organic wastes.

Third, the positive environmental impacts of the trade policy changes considered here are also generally modest, in the sense that indicators which improve all do so by less than 10 per cent. This means that free trade cannot be counted on in and of itself to significantly reduce environmental problems.

Fourth, the results for the case where technology is constant are not substantially different than when technology is allowed to vary in response to trade liberalization. Nevertheless, the results differ in ways relevant to environmental quality in some cases. The most important difference involves hazardous wastes, which decline moderately given constant technology but decline little or even increase when technology is variable. This suggests that it is important for environmental purposes to model the response of technical change to trade.

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