Welfare Effects of Trade Liberalization and Land Degradation in Indonesia[1]

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ABSTRACT

This paper uses the Global Trade Analysis Project model to help determine the welfare effects of trade liberalization and the resulting land degradation in Indonesia. Off-site environmental damage and on-site productivity impacts are simulated along with intersectoral and interregional economic effects. Results indicate that with the implementation of Uruguay Round liberalization, Indonesia's soil erosion may increase a little. The costs of this increased erosion are small relative to the welfare increases resulting from the trade liberalization. Systematic sensitivity analysis for key environmental parameters suggests that the results are fairly robust.

1. INTRODUCTION

To help determine the welfare effects of trade liberalization and the resulting land degradation in Indonesia, the Global Trade Analysis Project (GTAP) model is extended to include environmental effects. Off-site environmental damage and on-site productivity impacts are simulated along with intersectoral and interregional economic effects.

Trade liberalization may have both positive and negative impacts on the natural environment. Since ambiguous environmental outcomes are possible, quantification of the economy-environment linkages is necessary. An understanding of the relative importance of the various impacts is needed for prioritising by both researchers and policy makers [Anderson and Strutt 1996]. This paper aims to contribute to the relatively sparse literature on quantifying the welfare implications of the environmental impacts of trade policy changes for a large developing country.

2. MODELLING ENVIRONMENTAL EFFECTS

Computable general equilibrium models can be used to simulate and analyse policy changes having economy-wide impacts. Many policy reforms such as trade liberalization -- even if directed to just one sector -- affect other sectors of the economy. This can only be captured in a multisectoral model. The movement of activity between sectors is important when considering environmental effects, since an environmental improvement in one sector may be at the expense of degradation in other sectors. Furthermore, most reforms are piecemeal and the impacts depend in part on remaining distortionary policies, again requiring a system-wide analysis.

Increasing levels of experience and improved computational capability have led to significant advances in CGE modelling in recent years. Extending these models to incorporate non-marketed environmental impacts can further our understanding of the implications of policy changes. If values can be attached to the various types of environmental damage, a

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fuller welfare analysis is possible [Anderson and Strutt 1996]. Computable general equilibrium models have tight theoretical specifications and, unlike econometric models, can provide insights into changes for which there is no historical experience [Dixon and Parmenter 1994]. This makes them particularly attractive for modelling policy changes and environmental effects.

2.1 Modelling Land Degradation in Indonesia

The environmental links of agricultural production are two-way, with agricultural production affecting environmental quality and environmental quality affecting agricultural production. In Indonesia, soil erosion appears to be one of the most significant environmental problems caused by agricultural production. The World Bank estimates that soil erosion on Java costs the economy an estimated US$340-400 million per year (in 1989 dollars). Of this, nearly 80 percent is due to declines in the productivity of agricultural land, with 20 percent due to off-site costs such as siltation of irrigation systems and the loss of reservoir capacity [World Bank 1994]. These costs of erosion represent approximately 0.4 percent of total GDP or 2 percent of agricultural GDP. This is significant for a country that has achieved only a little over 2 percent average annual growth in agricultural production so far this decade.

Although there is some evidence that soil erosion does not seem to have a major impact on land productivity in countries such as the US, it is a far greater problem in tropical countries such as Indonesia. For example, average erosion rates in the US are estimated at about 0.7 tons of soil/ha/yr. This is compared with overall erosion rates in Java of around 6-12 tons/ha/yr on volcanic soils and much higher losses on limestone soils and agricultural land [World Bank 1990]. These high erosion rates are mainly due to the high level and intensity of tropical rainfall, and the loss of ground cover on steep terrain.

As farmers increase their production, *certeris paribus*, they tend to generate more erosion. The erosion damage can cause on-site productivity losses or off-site environmental damage. Farmers may respond to the on-site productivity effects [Barrett 1991]. However, even if they take on-site costs into account in their decision-making, there are few incentives for farmers to take account of the off-site impacts of their activities.

Both off-site environmental damage and on-site productivity effects are modelled here. The comparative-static GTAP model assumes optimizing behaviour by producers and consumers, subject to the various constraints of the economy [Hertel 1997]. Extensions to GTAP for the work presented here make minimal changes to the structure of the model and ensure that the consistency of the benchmark data is preserved. Environmental data is exploited without introducing a large number of parameters for which no data exists.

2.2 Off-site Environmental Damage

For resources that do not have stock feedback effects, environmental degradation can be modelled either as a factor of production [López 1994], or as a joint product in output [Copeland 1994, Tobey and Reinert 1991]. Off-site effects are modelled here as the latter, that is, driven by the level of production inputs and technology in the environmentally degrading sector.

Assume that there are $j=1,\ldots,n$ sectors, and that the amount of erosion (E_j) in each sector depends on the quantity of land used in that sector. Total land degradation (D) is defined in equation (1) as the sum of erosion across all sectors:

$$D = \sum_{j=1}^{n} E_j \qquad (1)$$

It follows that the proportional change in total erosion (d) can be expressed as equation (2):

$$d = \sum_{j=1}^{n} e_j \beta_j \qquad (2)$$

where

$$\beta_j = \frac{e_j}{\sum e_j} \quad \text{and} \quad \sum_j \beta_j = 1$$

The term e_j indicates the percentage change in the corresponding upper case variable. This method of calculating environmental damage follows Coxhead and Shively [1995]. When used with the GTAP model, it has the important advantage of only requiring estimates of β_j, the share of total erosion contributed by each sector in the benchmark year. All other data and parameters necessary to determine the change in erosion are available in the standard GTAP database. Large changes to the core model and database are therefore unnecessary.

For the effects of off-site environmental externalities, damage functions are appended to the standard GTAP model, with values for the new parameter β_j specified. The change in total erosion and the resulting off-site damage due to shifts in land use can be calculated. This makes any trade-off between income growth and environmental damage more explicit.

2.3 On-Site Productivity Effects

Production feedback effects are modelled to capture the adverse impact of on-site soil erosion on land productivity. The effect of land degradation is captured in the modified version of the GTAP model through use of a land quality shifter parameter. As land quality deteriorates due to erosion, additional units of land (and other primary factors) are required to sustain the same level of output. Use of such a feedback parameter mimics the deterioration in land quality and productivity when erosion occurs [see Strutt 1997].

For Indonesia, the adverse effects of on-site soil erosion are assumed to cause a reduction in land productivity in some agricultural sectors. Repetto et al. [1989] calculate average productivity losses to be 6.8 percent on erosion-sensitive crops such as maize and 4.3 percent on less sensitive crops such as cassava. We follow this work and assume that the grain sector exhibits a 6.8 reduction in land productivity. The non-grain crops sector includes staple and estate crops. It is assumed that 50 percent of the crops are erosion-sensitive, which leads to the assumption of a 5.6 reduction in land productivity for the non-grain crop sector. No adverse productivity effects are assumed in other agricultural sectors.

3. EFFECTS OF TRADE LIBERALIZATION

We model the effects of multilateral trade liberalization using a multi-regional general equilibrium model closure. This closure captures the changes in trade flows and the substitution in production and consumption that occurs between commodities. Prices, output levels and incomes are endogenous for all regions. Policy variables, factor endowment levels and technical change variables are exogenous. The full 30 region, 37 sector Version 3 GTAP database is aggregated to 6 regions and 15 sectors. The regional aggregation used includes Indonesia (IND), China (CHN), high income APEC economies (APH), developing APEC economies (APD), the other high income countries of Western Europe (HIG) and the rest of the world's developing and transition economies (ROW). The model is implemented and solved using GEMPACK [Harrison and Pearson, 1996].

3.1 Uruguay-Round Trade Liberalization

A Uruguay Round trade liberalization is simulated from the GTAP 1992 base. Tariffs are lowered to post-Uruguay Round levels. The GTAP database provides post-Uruguay Round protection vectors which draw on extensive work by the World Bank [McDougall 1997]. The export tax equivalents of MFA quotas are removed and agricultural export subsidies are reduced.

When protection is reduced, interregional and intersectoral shifts in economic activity are simulated. Table 1 shows the effect of Uruguay Round trade liberalization on welfare. Column 2 shows the percentage change in aggregate per capita utility. Projected changes in economic welfare, as measured by an equivalent variation in income, are shown in the third column. These welfare measures incorporate the impact of on-site environmental damage on land productivity.[2] The trade liberalization simulated increases welfare for most regions, particularly Indonesia and other developing APEC economies. Welfare is projected in these regions to increase by 0.86 and 0.77 percent or US$1018 and US$6268 million respectively. It is assumed that China does not liberalize its markets or enjoy the benefits of improved market access due to the removal of MFA quotas. China is therefore projected to experience a 0.29 percent welfare decline in these simulations.

[2] Welfare changes reported in Table 1 do not include the off-site costs of damage discussed in section 3.2.

Table 1: Welfare effects of Uruguay Round liberalization

(1) Region	(2) Change in per capita utility (%)	(3) Change in welfare (US$m)	(4) Allocative efficiency effects (US$m)	(5) Terms of trade effects (US$m)	(6) On-site productivity effects (US$m)
IND	0.86	1018	834	180	3.9
CHN	-0.29	-998	-1027	29	0
APH	0.27	25454	18699	6768	0
APD	0.77	6268	9679	-3395	0
HIG	0.16	11536	11691	-153	0
ROW	0.06	1555	4986	-3430	0

Decomposition of these welfare effects is provided in the last three columns of Table 1. Welfare effects are broken down into three components: allocative efficiency effects, terms of trade effects and on-site productivity effects [Huff and Hertel 1996].[3] Allocative efficiency gains result when resources are reallocated into areas of more efficient production. These are reported in column 4 and are positive for all regions except China. This highlights the importance of multilateral liberalization to prevent increased relative distortions in regions such as China which are not party to the agreement. The contribution to welfare of terms of trade effects are reported in column 5. Terms of trade deteriorations for the developing APEC economies and for the rest of the world are more than offset by improvements in domestic resource endowment use. Inclusion of on-site productivity effects for changes in land use in Indonesia makes only a small change to welfare. Column 6 of Table 1 shows that productivity effects make less than a 0.4 percent contribution to welfare for Indonesia. For other regions, no impact on land productivity is modelled.

3.2 Change in Erosion and Off-Site Damage

Table 2 reports the projected change in erosion following trade liberalization. To examine the off-site environmental damage of soil erosion in Indonesia, we analyse changes in land use. In particular, we examine the shift of land between more and less erosive crops as a result of trade liberalization. Column 2 shows the initial erosion share for each sector [see Strutt 1997], and the simulated change in land use is reported in column 3. The resulting aggregate change in erosion is shown in the final column.

Table 2: Change in soil erosion

(1) Sector	(2) Initial erosion share (%)	(3) Change in land use (%)	(4) Change in erosion (%)
Coarse grains	43	2.79	1.20
Non-grain crops	46	-0.93	-0.43
Forestry[4]	11	-0.78	-0.09
Total			0.69

The simulation results project a 0.69 percent increase in aggregate erosion in Indonesia following Uruguay Round liberalization. Although land use is reduced by almost one percent in both the non-grain crop and the forestry sectors, it increases by almost three percent in the coarse grains sector. Given World Bank estimates of the annual off-site costs of erosion for Java, the increase in soil erosion projected here suggests an increase of perhaps US$0.6 million in off-site damage costs. These costs are less than 0.1 percent of the projected increase in welfare due to trade liberalization.

[3] The summation of columns 4, 5 and 6 may not equal the change in welfare reported in column 3 due to marginal utility of income effects. The effects are small in this simulation and simply reflect the non-homothetic preferences assumed in the standard version of GTAP [Huff and Hertel 1996].

[4] The standard version of GTAP is modified to allow some land movement between forestry and agriculture.

The erosion increases reported may be overstated to the extent that the comparative static analysis used ignores important long run effects and political benefits. For example, as world incomes grow further,[5] there may be a global improvement in soil caused by the shift away from producing staples, especially staple grains [Lindert 1996]. In addition, significant erosion problems are caused by poor households seeking to increase immediate food production by using cropping methods that result in high soil erosion levels from their rainfed lands [Barbier 1990]. Increased incomes may reduce these problems and as land tenure becomes more secure, farmers may guard the productive capacity of their land more carefully.

3.3 Systematic Sensitivity Analysis

In simulations such as that presented here, results often hinge crucially on the values of key exogenous inputs. When precise information is not available, it may be more appropriate to specify distributions. Systematic sensitivity analysis (SSA) is an emerging technique that can incorporate information on distributions, as opposed to single point estimates, in computable general equilibrium models. Arndt [1996] developed the SSA technique from recent advances in the area of numerical integration and its application to economic problems [DeVuyst and Preckel 1996]. The procedure automates solving the model as many times as necessary, once the user has set it up and started it running [Arndt and Pearson 1996].

SSA analysis is conducted for the land productivity feedback parameters used in this paper. A symmetric triangular distribution is assumed. For coarse grains, a mean of -6.8 and a minimum value of -13.6 are used. Similarly, for non-grain crops, a mean of -5.55 and a minimum value of -11.1 are used. The welfare results appear fairly robust to assumptions made about the effects of soil erosion for on-site productivity. The mean of the equivalent variation in income is US$1018 million, while the standard deviation is US$130 million. This is despite the assumption that erosion may cause land productivity losses ranging up to almost 14 percent.

[5] For an application using GTAP which projects the world economy to the year 2005 before conducting a Uruguay Round liberalization, see Anderson et al. [1997].

4. CONCLUSIONS

The inclusion of environmental effects in a global trade model can provide a fuller welfare analysis of the effects of economic policy changes. Results presented in this paper suggest that, for Indonesia, there may be a slight increase in soil erosion accompanying trade liberalization. Relative to the welfare gains from trade liberalization, the costs of the damage caused by this increased erosion are small. Systematic sensitivity analysis of the key environmental parameters indicates that these results are fairly robust.

Measuring the environmental impacts of economic policy reform is not an exact science. Complex modelling is hindered by scarce environmental data and uncertainty. However modelling what we are able, and opening the issue to debate, may be an efficient way of improving our understanding and helping to ensure the best outcome, given incomplete information. This work complements more micro-level studies and it can be extended to cover other sectors and regions.

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