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ESTIMATING ENVIRONMENTAL EFFECTS OF TRADE AGREEMENTS WITH GLOBAL CGE MODELS: A GTAP APPLICATION TO INDONESIA

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ABSTRACT

ESTIMATING ENVIRONMENTAL EFFECTS OF TRADE AGREEMENTS WITH GLOBAL CGE MODELS: A GTAP APPLICATION TO INDONESIA

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Provided globally optimal environmental and other policies are in place, most-favoured-nation (MFN) trade liberalizations will always improve global economic welfare. But since the proviso is not met in practice, empirical studies of the environmental and resource depletion effects of such reforms are needed to determine whether trade reform is still worthwhile. This paper provides a methodology for doing that, using a modified version of a multi-country economy-wide model. Attention focuses on environmental effects in just Indonesia, a large newly industrializing country that is rich in natural resources and committed to taking part in major multilateral and regional trade liberalizations over the next two decades. A modified version of the global CGE model known as GTAP is used to project the world economy to 2010 and 2020 without and with those reforms. An environmental module is attached to the Indonesian part of that global CGE model so as to measure the effects of changes in economic activity on air and water pollution. The proportional contributions to environmental indicators of changes in the level and composition of output, and changes in production techniques, are identified. A base case projection without trade reform is compared with alternative scenarios involving full global implementation of WTO members' Uruguay Round commitments by 2010, and the additional move to MFN free trade by APEC countries by 2020. The study suggests that, at least with respect to air and water pollution, trade policy reforms slated for the next two decades would in many cases improve the environment and reduce the depletion of natural resources and in the worst cases would add only slightly to environmental degradation -- even without toughening the enforcement of existing environmental regulations or adding new ones.

Key words: Trade and environment, Indonesia, global CGE model

JEL Codes: F13, F14, F15, F17, O13, Q2, Q4

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Most-favoured-nation (MFN) trade liberalizations will always improve global economic welfare even in the presence of environmental externalities, provided optimal environmental policies are in place (Anderson and Blackhurst 1992; Corden 1997). However, in a world in which national environmental standards differ markedly between countries and international environmental spillovers are significant, globally optimal environmental policies will differ from nationally optimal ones. That, plus the fact that in many (especially developing) countries the enforcement of environmental policies is often less than optimal even from a national viewpoint, raises in some people’s minds (e.g., Chichilnisky 1994) the question of whether liberalizing trade between rich and poor countries is desirable. To begin to assess whether the standard gains from trade are sufficient to outweigh any loss in welfare due to added environmental damage, and to foreshadow the need for environmental policy changes to accompany trade reforms, empirical studies of the resource depletion and environmental degradation effects of such reforms are needed.

Various methodologies using global or national computable general equilibrium models are beginning to be used for this purpose. An example of a global model is Anderson and McKibbin (1999), who examine the effects on carbon emissions of reducing distortions to world coal markets. An example of a national model is that developed for China by Xie (1996). In the present paper we draw on our recent study (Strutt and Anderson 2000) which is a blend of those approaches: a multi-regional global model is used to project the world's national economies to the end of the period of implementation of a trade agreement, and then attention is focused on the environmental effects of that in just one country, namely Indonesia. That country was chosen because it is a large newly industrializing country that is rich in natural resources and committed to taking part in major multilateral and regional trade liberalizations over the next two decades, and has a readily useable set of environmental data.

Section 1 describes how a modified version of the global economy-wide model known as GTAP is used to project the world economy to 2010 and 2020 without and with those trade reforms. (This long-run view allows us to abstract from the disruptions of the current financial and political crisis.) As explained in Section 2, an environmental module is attached to the Indonesian part of that global model so as to measure the effects of structural and policy-induced changes in economic activity on air and water pollution in Indonesia. The results, presented in Section 3, identify the proportional contributions of changes in the aggregate level and composition of output, and in production techniques, to changes in environmental indicators. A base case projection with no trade reform (and no environmental policy changes) is compared with alternative scenarios involving (a) full global implementation of Uruguay Round commitments, and (b) the additional move to MFN free trade by APEC countries by 2020. The paper concludes in Section 4 with suggestions for extending this method of environmental assessment.

1. Projecting the level and composition of output to 2020 without and with trade policy reforms

Rapid economic development and on-going policy reforms in Indonesia and other countries of the world will change substantially the level, composition and location of production and consumption during the next two decades. We project global economic growth and structural changes for the periods 1992-2010 and 2010-2020. We also model the Uruguay Round and APEC trade liberalization commitments over those periods. The Uruguay Round agreements should be fully implemented by 2005, before the end of the first period, and 2010 is the date agreed at Bogor in November 1994 for completion of trade liberalization by APEC industrialised countries. The year 2020 was agreed by Indonesia and other APEC developing countries to be the date for completing their move to free trade, and it also coincides with the end of Indonesia's Second Long Term Development Plan.

We use Version 3 of the Global Trade Analysis Project (GTAP) database and model of national and international markets for all products and countries/regions of the world.[1] The full GTAP database divides the world economy into 37 sectors and 30 countries or country groups (including the 16 major APEC economies). In order to keep the present analysis and presentation of results tractable, the data base is aggregated up to 23 product groups and to 4 regions in addition to Indonesia. There are numerous advantages of using such a global, economy-wide CGE model even if, as with the GTAP model used here, it is comparative static in nature. The economy-wide approach makes explicit the assumed sources of economic growth that expand the demand for and supply of various products; it ensures countries can import only what they can pay for through exporting or borrowing; and it includes in the base scenario the inter-sectoral structural changes that normally accompany economic development. The advantage of using a global model rather than a national one, even though the primary focus of this paper is on results for Indonesia, is that the economic growth and structural and policy changes of other countries can be incorporated explicitly. This ensures that those changes abroad in combination with Indonesia's changes are used to generate new terms of trade for Indonesia. But it also allows the resource depleting effects of international events on Indonesia to be compared with those effects on other economies.

Following the methodology used in Hertel et al. (1996) and Anderson and Pangestu (1998), we use World Bank projections together with the GTAP Version 3 data base and model to generate market projections to the year 2020.[2] By projecting the world economy from 1992 to 2010 before looking at the effects of Uruguay Round trade policy reforms and to 2020 before APEC trade reforms, we hope to get a more realistic measure of the long-run effects of these trade reforms. A projection of the world economy to 2010 is generated assuming no trade policy changes. Then the model is re-run several times: with the Uruguay Round being fully implemented, with China included in the WTO;[3] and then with APEC liberalization commitments also being implemented by 2020. We use a carefully constructed set of Uruguay Round shocks, to take into account the reality that actual reforms in Indonesia and elsewhere, particularly for farm products, will be much less than was earlier expected, thanks to 'dirty tariffication' (see Hathaway and Ingco 1996). The scenario for 2010 with the Uruguay

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[1] See Hertel (1997, especially Chs. 2 and 3) and McDougall (1997) for detailed descriptions of the GTAP model and v3 data base. Updated information is available at: http://www.agecon.purdue.edu/gtap.

[2] See Strutt and Anderson (2000) for further details.

[3] For a discussion of Uruguay Round implementation without China, see Strutt and Anderson (2000).

Round fully implemented is the starting point from which to project the world economy to 2020. This too is done assuming no further trade policy changes as a base case, and that scenario is then compared with one in which the remaining trade barriers of APEC countries are removed.

How do all these changes affect the world economy? Even without the Uruguay Round being implemented, the real value of global output is projected to increase by 65 per cent between 1992 and 2010, and then by a further 35 per cent by between 2010 and 2020 after the Uruguay Round is implemented but without any APEC regional liberalization. Developing countries are projected to gain enormously in significance, particularly developing APEC economies which are projected to more than double their share of world output, from 6 to 14 per cent during the 1992-2020 period, and treble their share of world trade.

Indonesia in particular is projected to almost treble its contribution to world output (from 0.5 to 1.5 per cent), to increase its real volume of output and trade more than six-fold over the projection period, and to change the sectoral shares of its GDP substantially. Indonesia's agricultural and other natural resource based sectors continue to decline in relative importance as textiles and other light manufacturing industries grow. The grain sectors' share of GDP is projected to roughly halve by 2010, for example, and to fall by a further one-third or more in the subsequent decade -- even though the absolute level of output keeps rising in these as in all other sectors. Also, while the depletion of natural resources continues, forestry, fishing and mining outputs are projected to grow much less rapidly than aggregate national output.

Against these massive structural changes that traditionally accompany economic growth, the model's projected changes caused even by very large policy shocks are relatively modest. Columns 3 and 4 of Table 1 show, for example, how much additional impact by 2010 the Uruguay Round's implementation would have on the output of different sectors in Indonesia, and then how much extra impact the APEC reforms to 2020 would add. The impact of these reforms would have to be judged as rather small in most sectors, relative to the large changes that normal economic growth is projected to generate. Nonetheless they bring substantial increases in Indonesia's economic welfare as traditionally measured even by comparative static models such as the one used here: the Uruguay Round with China included boosts real GDP for Indonesia by 1.4 per cent, and the APEC reform adds another 1.2 per cent -- even ignoring the likelihood that GDP growth would be accelerated by reform.

However, such welfare measures ignore changes in resource depletion and the environment as a consequence of the increased level and changed composition of Indonesia's output. Many environmental groups would claim that adverse resource depletion and environmental degradation effects of trade policy reform will be substantial, but very few empirical studies have sought to test that hypothesis. On environmental degradation, the following section suggests a way to examine how the changes in the aggregate level of output, the composition of that output and in the inputs and technologies used is likely to impact on air and water pollution levels. The paper then provides some empirical results for Indonesia's environment, followed by a discussion of results on resource depletion.

2. Adding an environmental module to the projections model

Accompanying economic growth and market reform are changes in the scale of output, in tastes, in the relative size of sectors, and in inputs and production technologies. These can all affect the level of pollution. How can we model these interacting forces and decompose the projected changes in environmental degradation to determine how they drive environmental change?

The model providing the projections of structural change and trade liberalization presented above provides a starting point, to which needs to be added environmental side modules to analyse the implications of these economic changes for environmental degradation.[4] In this paper we use side modules to project environmental outcomes in Indonesia for water use, water pollution and air pollution. The data for the side modules are based on a comprehensive environmental input-output data set prepared by Duchin et al. (1993) using data collected in Indonesia for 1985 and 2020 by industry for various types of environmental degradation. The authors use a case study approach to project anticipated changes in technology to 2020. Twelve case studies generated data reflecting the views of experts assuming a continuation of current policies. Specialists such as chemical engineers, hydrologists, environmental scientists, energy experts and agricultural scientists were consulted on the technologies likely to be adopted in coming decades.[5] For water use there are data on the volume of water used and discharged by sector. Four measures of the water pollution content of the effluent are provided: biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved solids (DS), and suspended solids (SS). The available air pollutant indicators are carbon dioxide and oxides of sulphur and nitrogen.[6]

Based on the data from Duchin et al. (1993), we assemble a matrix of environmental coefficients to estimate the environmental impact per unit of economic activity in each sector for 1992, 2010 and 2020 by assuming trends in environmental parameters per unit of output are linear over the period 1985-2020. The GTAP 1992 benchmark database for Indonesia is calibrated to this 1992 matrix of total emissions to derive environmental damage coefficients per unit of GTAP sectoral output in that base year. The proportional changes in these environmental coefficients over time are then multiplied by the GTAP 1992 environmental coefficients to obtain GTAP environmental coefficients for 2010 and 2020. This approach captures the expected change in environmental coefficients in a consistent way that is used to augment GTAP analysis.

Three sources of environmental effects of policy changes are able to be identified: the change in the level of aggregate economic activity, the change in the contribution of each sector to output, and the change in production technology. This decomposition is useful for disentangling the causes of changes in environmental damage.[7] Define the total change in pollution (P) as the sum of the changes in pollution in each sector $\left(P_j\right)$:

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[4] The approach of augmenting CGE models with environmental side models has been taken by a number of researchers. For example, Bandara and Coxhead (1995) look at soil erosion in a single country model. Perroni and Wigle (1997) use an innovative side model to analyse global externalities and abatement costs with GTAP.

[5] Other scenarios are also presented where the government is assumed to place heavier emphasis on environmental protection and resource conservation. Since we do not explicitly model improved environmental policies here, only the scenario of current trends is used.

[6] Pollution from final consumption by households is not included in the model, for want of data.

[7] The decomposition developed here is in some ways similar to the “scale”, “composition” and “technique” effects of income growth on the level of environmental emissions discussed by Dean (1996, 1999). Beghin et al. (1997, 1999) also discuss such a three-way decomposition.

$$P = \sum_{j=1}^{n} P_j \; .$$

The change in pollution in each sector *j* is the sum of the "aggregate activity" effect $\left(A_j^o\right)$, the "intersectoral composition" effect $\left(C_j^o\right)$, and the "technology" effect $\left(T_j\right)$:

$$P_j = A_j^o + C_j^o + T_j$$

In the aggregate activity effect, increased economic activity leads to increased demand for all goods and services and therefore increased emissions. The change in output due to the aggregate activity effect is the proportional change in aggregate real output in the economy (g) multiplied by the initial output in each sector $\left(X_j\right)$. This gives the change in the scale of output in each sector with all sectors growing at the aggregate growth rate of the economy. The change in the scale of output in each sector is then multiplied by the initial environmental coefficient for each sector $\left(E_j^o\right)$ to give the change in environmental emissions in each sector due to the aggregate activity effect:

$$A_j^o = X_j * g * E_j^o$$

The second effect is the intersectoral composition effect. Because some sectors are more polluting than others, changes in the composition of output will change pollution, even if aggregate output were to remain constant. The intersectoral effect is measured by allowing the composition of output to change while maintaining aggregate output at its initial level. Some sectors contract and others expand. This has some similarities with Dean's (1996) composition effect, where emissions decrease if income growth shifts preferences toward income elastic cleaner goods, but we model the general equilibrium-determined intersectoral effects. Both producers and consumers respond to the changed incentives, given their behavioural functions and the various constraints on the economy. Demand and supply of each commodity in each region of the world respond to changing relative prices, given the elasticities implicit for each sector. The change in sectoral output due to the intersectoral composition effect is found by multiplying the initial output in each sector by the difference between the proportional change in output in that sector (x_j) and the aggregate proportional change in output in the economy (g) to give the change in the relative size of each sector. This change in the contribution of each sector is multiplied by the initial environmental coefficient for each sector to give that sector's change in environmental emissions due to the intersectoral composition effect, C_j^0, where

$$C_j^o = X_j * (x_j - g) * E_j^o$$

Thirdly, there is the "technology" effect, which is modelled using Duchin et al.'s (1993) set of environmental parameters reflecting expert opinion on anticipated changes to production methods.[8] Changes in technology will change the amount of degradation caused by each unit of output in each sector. Total emissions with the new coefficients are compared to total emissions with the old environmental coefficients in place. The first square bracketed term of the following equation reflects the new environmental coefficient $\left(E_j^n\right)$ applied to both the aggregate activity and the intersectoral composition components of changes in output. The second square bracketed part of the equation reflects the idea that the initial output in each sector will

[8] For a discussion of other possible components of the technique effect, see Fredriksson (1999).

also be produced using the new technology and will therefore contribute to a change in emissions.

$$T_j = \left[\left(A_j^n - A_j^o\right) + \left(C_j^n - C_j^o\right)\right] + \left[X_j * \left(E_j^n - E_j^o\right)\right]$$

where

$$A_j^n = X_j * g * E_j^n$$

and

$$C_j^n = X_j * (x_j - g) * E_j^n$$

However, for policy changes such as trade liberalization where we start from the appropriate updated database, we assume that the new technology is in place and that the trade reform itself does not change the environmental damage coefficients.

3. Empirical projections of environmental impacts in Indonesia of structural and policy changes to 2020

3.1 Projected environmental effects due to growth and structural changes

This section uses the detailed environmental side modules to analyse some of the environmental implications of first the growth and structural changes projected for Indonesia and then the trade policy changes by 2010 and 2020.

Table 1 shows the proportional changes in output due to structural changes associated with economic growth projected over that period, assuming no trade policy changes. Changes over the subsequent decade also are shown. With the large growth in the economy projected from 1992 to 2010 and 2010 to 2020, all sectors exhibit increased output levels in Indonesia but some expand much more than others. We use environmental side modules to estimate the effects of these changes in output on air and water pollution.

Air pollution

Atmospheric emission changes are estimated for carbon dioxide and oxides of sulphur and nitrogen. Large increases are projected for all of these air pollutants however this finding is not surprising given that the Indonesian economy is projected to grow by 215 per cent between 1992 and 2010 and a by further 95 per cent by 2020. As shown in Table 2, carbon emissions increase by 134 per cent in the first projected period and by 56 per cent for the decade to 2020. Sulphur oxides increase by 132 and 50 per cent and nitrogen oxides increase by 162 and 65 per cent.

The aggregate output effect increases each sector’s output, while the technology and intersectoral composition effects may add to or dampen the impact of increased aggregate output on emissions. Table 2 decomposes these air pollution effects to give an indication of the relative magnitudes of the aggregate activity, the intersectoral composition and the technology effects. The table suggests the aggregate activity effects are the main driving force behind the increase in projected emissions, but that the intersectoral composition effects of structural change adds to that effect for all air pollutants. This is because there is a relatively high increase in the contribution to output of high air polluting sectors such as the electricity, water and gas sector and the trade and transport sector. Sectors that are not very high air polluters, such as agricultural sectors, tend to decline in relative importance.

While the aggregate activity effect, and to a much lesser extent the intersectoral composition effect, increase air pollution during the period to 2020, many sectors’ emissions of carbon and oxides of sulphur and nitrogen grow less rapidly than output because of improvements in energy efficiency. This is shown by the technology effect which is negative for all air pollutants in Table 2, reflecting the improved technologies expected to become available.

Water use and pollution

Manufacturing sectors face two offsetting trends in their use of water. Growth occurs in water-intensive sectors like pulp and paper, but new technologies for conserving water are expected to be adopted over time. Overall there is a significant increase in water uptake in the textiles, other manufacturing and pulp and paper sectors. Even by 2010 these more than double their water use, while household water use increases by almost 50 per cent.[9] However increases in water use are dwarfed by the savings in water uptake for paddy rice, which is the largest user of water in our model. That comes from the significantly improved efficiencies anticipated in irrigation delivery systems as well as from the changing intersectoral composition of output. As a consequence, total water withdrawals fall over the projection periods, by 4 per cent to 2010 and by a further 36 per cent by 2020.

Between 1992 and 2010, we project water discharge to increase by 126 per cent, with a further 29 per cent increase by 2020 (column 2 of Table 2). The decomposition in Table 2 shows that the intersectoral composition effect augments the aggregate activity effect a little. The relative increases are in textiles, pulp and paper and other manufactures, which are all large producers of waste water. However, improved technologies dampen the effect of increases in water discharged.

The water pollution changes we model are biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved solids (DS) and suspended solids (SS). These emissions are assumed to be determined by the quantity of waste water produced. Once we have calculated the proportional change in water output for each sector, we can estimate the change in water pollution by sector. Because of the aggregate activity effect, emissions of all water pollutants except for dissolved solids rise between 1992 and 2010 (Table 2(a)). However, emissions rise by significantly less than the proportional increase in total output in Indonesia. This is mainly due to the improved technology assumed to be available in 2010. The intersectoral composition effect for all water pollutants, with the exception of dissolved solids, is positive due to the increased relative significance of the polluting industries. The composition effect in both projected periods moves production into the sectors we model as being the most important producers of water pollutants, particularly textiles, pulp, paper, and other manufactures. For dissolved solids, the composition effect is negative with the reduced significance of the food processing sector.

For the period to 2010, the assumed technology effect offsets over 80 per cent of the aggregate activity and intersectoral effects for all water pollutants. And for the period to 2020, the technology effect is sufficiently strong to overturn the positive aggregate activity and intersectoral effects to give a net reduction in pollution for all water pollutants.

[9] Increases in household water use are exogenous, they are taken from estimates in Duchin et al. (1993), assuming Indonesia’s population increases to 263 million by 2020.

3.2 Projected environmental effects of Uruguay Round and APEC trade reforms

How much difference will it make to those environmental effects of economic growth to impose on Indonesia and others some trade reforms? Column 3 of Table 1 shows the proportional change in output due to Uruguay Round liberalization. The last column shows the projected sectoral changes in output due to APEC liberalization. Some sectors reduce and other sectors increase their output level because of trade reform. This contrasts with the structural change projections where all sectors increase their output (columns 1 and 2). We therefore can expect the composition effects to be much stronger relative to the aggregate activity effects in these trade reform cases, in contrast to the growth and structural change scenarios discussed above.

The results in Table 1, coming from a global model, include the effects on output levels in Indonesia of changes in protection and relative prices in other regions. The sector that experiences the greatest proportional increase in Indonesia with Uruguay Round implementation is textiles and clothing, with just under 40 per cent boost to output anticipated. With additional APEC liberalization, the effects on the textile sector are much less pronounced because MFA quotas are assumed to have been already phased out as part of the Round's implementation. The sectors that tend to do well with APEC reform are instead the coal and non-metallic minerals -- sectors which Indonesia's own policies tend to discriminate against. The corn (coarse grains) sector also is projected to do well.

What do these output changes do to pollution levels? Again, we consider effects on first air and then water, recognising that emissions will increase in some sectors and fall in others in response to Uruguay Round and APEC trade reforms.

Air pollution

Table 3(a) indicates that a *reduction* in air pollution is projected for Indonesia under Uruguay Round liberalization, rather than the increase feared by environmentalists. The reduction from 2010 baseline levels is 0.6 per cent for carbon and sulphur oxides and 1.0 per cent for nitrogen oxides. The decomposition in Table 3(a) shows that the aggregate activity effect adds to air pollution but the change in the intersectoral composition of output reduces air pollution by more.

When the total change in emissions is decomposed by sector, we find that the most significant reduction is contributed by the trade and transport sector. The output of textiles rises more than that in any other sector, but since it is starting from a relatively low base of air emissions, the increase in air pollutants from this sector is more than outweighed by reductions occurring in other sectors. If China were not included in the WTO and hence by assumption does not liberalize its trade or gain expanded access to US and EU textile and clothing markets, the reductions in Indonesia's air pollution almost double relative to the reductions shown in Table 3(a). This is primarily because the Indonesian textile and clothing sector does not grow as much when China is included and hence that sector does not pull as many resources away from other more-polluting sectors. However, the greater carbon and other emissions in Indonesia are possibly more than offset by a reduction in emissions in China following its accession to WTO and thereby its assumed greater access to textile markets in the United States and the EU.[10]

[10] When China is excluded, the group of 'Other APEC developing economies' (which includes China) expand their output of textiles and clothing by only 8 per cent following Uruguay Round implementation, whereas with China included, that sector expands 25 per cent (Strutt 1998, Ch. 5).

With additional APEC trade liberalization, air pollution is projected to increase but, as shown in Table 3(b), the increases are only between 2 and 4 per cent. Moreover, a small number of sectors drive the results. For example, the trade and transport sector contributes over 45 per cent of the increase in air pollution (unreported further decomposition of results in Table 3(b). This makes it relatively easy to target that pollution with environmental taxes to reduce the impact of trade reform on emissions, should that small increase be considered a problem.

The key point to draw from these results, however, is that the air pollutive effects of even these major trade liberalizations is tiny (at less than 4 per cent of the base level), and is especially small compared with the increases that will accompany normal economic growth and structural changes.

Water use and pollution

Water withdrawals are reduced by both trade liberalizations. Table 3(a) shows a reduction in withdrawals of 0.3 per cent with Uruguay Round implementation, while Table 3(b) shows water withdrawals reducing a further 1.6 per cent with APEC trade reform. These water use reductions are largely due to a reduction in paddy output.

Most water pollutants also decline with Uruguay Round implementation, as shown in Table 3(a). The declines are just under 1 per cent for BOD, COD and dissolved solids, but there is an increase of just under 1 per cent in suspended solids. For APEC liberalization, Table 3(b) reports a 2.4 per cent increase in BOD and COD but reductions in solids of between 1 and 2 per cent. Thus as with air pollution, these results show that trade reform will at most add only a very small amount to water use and pollution, an amount that would not be discernible alongside the increased BOD and COD pollution associated with the general expansion of the economy over time.

Resource depletion

The impact of trade liberalization on natural resource depletion can be crudely inferred from changes in primary production. In the case of the Uruguay Round, the first column of Table 4 shows that most primary production is reduced by that liberalization. This suggests that less rather than more depletion of Indonesia’s natural resources will take place because of the Uruguay Round reforms. The natural resource impact of the Uruguay Round can be seen in Table 4 to be positive rather than negative in most other regions too. It is negative mainly in Western Europe (‘Other high-income economies’), where resource policies are well developed and could easily be adapted to cope with any undesired increase in exploitation. The final column of Table 4 shows that in aggregate the changes to natural resource use from the Round will be tiny.

4. Conclusions and future directions for research

If present environmental policies remain unchanged, projected economic growth and structural changes over the next two decades would, according to the above simulations, add to environmental degradation and resource depletion in Indonesia. This is not an argument against economic growth, of course, but rather for the need to introduce or strengthen the enforcement of environmental and resource policies to internalize some of the externalities associated with output and consumption expansion. When optimal environmental (and other) policies are in place and are continually adapted to remain optimal over time, it follows that economic growth enhances social welfare. There may be more environmental degradation or resource depletion, but at least those changes would be optimal from that society's viewpoint, given the actual or opportunity cost of avoidance or abatement. Likewise, trade reform can contribute to environmental damage and resource depletion, but again that will not be nationally welfare-reducing as long as optimal environmental (and other) policies are always in place.

A concern of some people, though, is that developing countries' environmental and resource policies may not be optimal even nationally, let alone from a global perspective, and that trade liberalization with no change in those environmental and resource policies could be bad for the environment. Hence the reason in the present empirical study for looking at trade reform without changing environmental and resource policies.[11] This case study of Indonesia suggests that trade policy reforms slated for the next two decades in some cases would improve the environment (at least with respect to air and water pollution) and reduce the depletion of natural resources in that country and in the worst cases would add only very slightly to environmental degradation and resource depletion even without greater enforcement of existing environmental and resource regulations or adding new ones. The increases in pollution, where they occur, are driven primarily by a small number of sectors which could be targeted with policies to help ensure no increase in emissions. The economic gains from the trade reforms and the scope for adopting well-targeted environmental and resource policies to reduce any serious damage are such that social welfare almost certainly is going to be improved by these liberalizations.[12]

This study uses environmental side modules to focus primarily on one country's resources and environment. We set up a framework for modelling and decomposing the major environmental impacts of growth and policy reform in as transparent a way as possible. The results presented here indicate sectors of particular concern, given available information and our choice of model.[13] Needless to say, caution should be used in interpreting the above results, particularly given the still poor quality of much environmental data.

Use of a global trade model facilitates some broad analysis of environmental effects in other countries. For example, we use changes in primary production to infer the natural resource impact of the Uruguay Round in Indonesia and other regions. We can also examine how changes in the composition of output in other regions following trade reform is likely to affect the environment. An example of this is the inclusion of China in the WTO that (hopefully) allows China greater access to US and EU markets under the Uruguay Round Agreement on Textiles and Clothing. We suggest that this would reduce Indonesia's capacity to expand exports of light manufactures and so keep resources in more-polluting activities in Indonesia -- but it would mean China

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[11] For more on modelling the responses of environmental policies to trade reforms (something not attempted in the present study), see the recent paper on Mexican agriculture by Beghin et al. (1997).

[12] Cole, Rayner and Bates (1998) apply emission coefficients to another set of Uruguay Round output results using GTAP and they place monetary values on the estimated changes in global emissions. While the latter values are open to question of course, their global results nonetheless are consistent with the above findings for Indonesia in suggesting that any increases in pollution from the Uruguay Round are likely to reduce developing countries' welfare gains from liberalization by much less than 2 per cent while *raising* the welfare gains to some advanced economies. Another recent empirical study of APEC trade reform by Unteroberdoerster (1998) also finds very small effects on the environment.

[13] There are of course more sophisticated methods of projecting economic growth, using endogenous growth and incorporating imperfect competition and scale economies.

moves away from some of its very pollutive coal-intensive heavy manufacturing, thereby potentially reducing not only local air pollution but also global warming. These results for other regions could be quantified by extending the environmental side modules developed here for Indonesia to other countries and regions included in the GTAP model. It may also be possible to extend the side modules to estimate monetary values for changes in some types of pollution as in Cole, Rayner and Bates (1998).

As improved environmental data become available, improved modelling of pollution across countries will be possible. Future versions of the GTAP data base will have an upgraded energy component that will facilitate improved modelling of air pollution across all regions.[14] More direct inclusion of emissions and abatement activities in the GTAP model may be desirable, rather than having just side modules.[15] Among other things, the model could then be modified to enable induced substitution towards less environmentally damaging output and the adoption of less-polluting technologies when environmental taxes are imposed or increased. Endogenizing environmental policies to income growth,[16] trade policy changes and changes in pollution, and including consumption pollution by various types of households (only one exists in the present model), would be other useful extensions. Modified versions of the models could also be used to examine the economic effects of underpricing environmental or resource inputs. For instance, water for farmers is underpriced in most countries: what would happen to world markets if all, or a subset of countries, created property rights over water or otherwise properly charged for water?

Clearly, this kind of research is in its infancy and has a rich future research agenda. The policy debate will increasingly demand informed answers to questions on the environmental effects of international agreements, and the environmental-economic interactions are too complex for adequate answers to be forthcoming without formal modelling. However, given the current paucity of many types of environmental data, only modest environmental modules may in many cases be appropriate until more progress is made in estimating environmental damage functions. A global model such as GTAP is an appropriate base which we can augment with environmental side modules, and over time, build environmental data and parameters directly into.

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[14] The weakness of the energy data in version 3 of GTAP led us to not focus particularly on energy in the current work. Details of the project aiming to collect consistent data on energy quantity flows, prices and taxes to be incorporated into future versions of the GTAP data base are available at http://www.agecon.purdue.edu/gtap/database/energy/index.htm. The process of incorporating such data directly into the GTAP model is explained in Malcolm and Truong (1999).

[15] This may be particularly important for environmental degradation which impacts on production. Strutt (1998, Ch. 3) focuses on land degradation in Indonesia and by incorporating the feedback effects of erosion damage on land productivity, she values the loss of production associated with that erosion.

[16] The reasons for expecting citizens to seek a tightening of environmental standards and regulations/taxes on pollution and resource depletion as incomes rise, at least after middle-income status is reached, have been canvassed by, among others, Selden and Song (1994), Grossman and Krueger (1995), and Hettige, Mani and Wheeler (1999).

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Table 1: Percentage changes in real sectoral output levels in Indonesia due to economic growth, 1992-2010 and 2010-2020[a] and following Uruguay Round and APEC trade reform

	1992-2010	*2010-2020*	*Uruguay Round, 2010*	*APEC liberalization, 2020*
Paddy rice	87	35	-0.3	-1.6
Other grains	23	1	4.7	14.9
Non-grain crops	58	15	-4.6	-13.4
Livestock	113	36	0.1	3.1
Forestry	100	43	-1.1	-0.2
fisheries	85	23	-0.7	-4.1
Coal	124	49	-7.1	18.4
Oil	114	64	-3.3	0.6
Gas	103	59	-3.4	0.7
Other minerals	131	82	-5.2	-1.6
Food processing	87	34	-0.3	-1.7
Textiles, clothing, leather	449	177	38.5	-2.6
Wood products	73	32	-2.4	1.2
Paper products	331	132	-3.7	6.7
Petroleum & coal products	253	121	0.5	-2.1
Chemicals, rubber & plastics	282	120	2.5	9.2
Non-metallic mineral prods.	267	125	-4.4	23.8
Other manufactured products	375	201	-12.3	-1.9
Electricity, water & gas	268	118	1.5	1.1
Construction	241	125	-0.1	-1.5
Trade & transport	304	120	-1.3	4.9
Other private services	293	114	-1.4	1.3
Other public services	447	61	-0.5	-1.0
Real GDP growth	**215**	**95**	**1.4**	**1.2**

[a] The projections for the period to 2010 maintain initial protection data, while those for the period 2010 to 2020 assume that the Uruguay Round, including China, has been fully implemented by 2010.

Source: Authors' model results

Table 2: Decomposition of changes in pollution as a consequence of economic growth and structural changes, Indonesia, 1992-2010 and 2010-2020

(a) 1992-2010	***Total pollution change***[a]		***Aggregate activity effect***	***Intersectoral composition effect***	***Technology effect***
Carbon (kt)	**65,346**	[134]	104,607	10,149	-49,409
Sulphur (kt)	**799**	[132]	1,302	214	-716
Nitrogen (kt)	**1,427**	[162]	1,897	392	-862
Water in (bm^3)[b]	**-12**	[-4]	685	-388	-309
Water out (bm^3)	**0.8**	[126]	1.3	0.7	-1
BOD (kt)	**81**	[52]	337	176	-433
COD (kt)	**341**	[64]	1,149	726	-1,534
DS (kt)	**-17**	[-46]	79	-47	-48
SS (kt)	**105**	[23]	1,002	638	-1,536

(b) 2010-2020	***Total pollution change***[a]		***Aggregate activity***	***Intersectoral composition***	***Technology effect***
Carbon (kt)	**63,982**	[56]	107,244	16,904	-60,166
Sulphur (kt)	**707**	[50]	1,323	276	-893
Nitrogen (kt)	**1,495**	[65]	2,165	366	-1,035
Water in (bm^3)[b]	**-109**	[-36]	296	-167	-236
Water out (bm^3)	**0.4**	[29]	1.3	1.0	-2
BOD (kt)	**-13**	[-5]	223	146	-382
COD (kt)	**-2**	[-0]	822	587	-1412
DS (kt)	**-13**	[-65]	19	-12	-19.5
SS (kt)	**-211**	[-37]	545	474	-1231

[a] Percentages changes from base case are shown in square parentheses.
[b] This does not include the change in household water use.

Source: Authors' model results.

Table 3: Decomposition of pollution effects for Indonesia from (a) Uruguay Round trade reform, 2010 and (b) APEC liberalization, 2020 (% change from 2010 or 2020 baselines shown in parentheses)

(a) Uruguay Round	*Total change*	*Aggregate activity*	*Intersectoral composition*
Carbon (kt)	**-733**	1,585	-2,318
	(-0.6)	(1.4)	(-2.0)
Sulphur (kt)	**-8**	20	-27
	(-0.6)	(1.4)	(-1.9)
Nitrogen (kt)	**-22**	32	-54
	(-1.0)	(1.4)	(-2.3)
Water in	**-0.8**	4	-5
(billion m^3)	**(-0.3)**	(1.4)	(-1.6)
Water out	**0.01**	0.02	-0.01
(billion m^3)	**(0.6)**	(1.4)	(-0.8)
BOD (kt)	**-2.0**	3	-5
	(-0.9)	(1.4)	(-2.3)
COD (kt)	**-6.5**	12	-19
	(-0.7)	(1.4)	(-2.1)
DS (kt)	**-0.05**	0.3	-0.3
	(-0.3)	(1.4)	(-1.7)
SS (kt)	**5.3**	8	-3
	(0.9)	(1.4)	(-0.5)

(b) APEC	*Total change*	*Aggregate activity*	*Intersectoral composition*
Carbon (kt)	**3,736**	2,124	1,612
	(2.1)	(1.2)	(0.9)
Sulphur (kt)	**72**	25	47
	(3.4)	(1.2)	(2.2)
Nitrogen (kt)	**144**	45	99
	(3.8)	(1.2)	(2.6)
Water in	**-3.0**	2.3	-5.3
(billion m^3)	**(-1.6)**	(1.2)	(-2.8)
Water out	**-0.002**	0.02	-0.02
(billion m^3)	**(-0.1)**	(1.2)	(-1.3)
BOD (kt)	**5.4**	2.7	2.7
	(2.4)	(1.2)	(1.2)
COD (kt)	**21.1**	10.4	10.8
	(2.4)	(1.2)	(1.2)
DS (kt)	**-0.13**	0.09	-0.21
	(-1.8)	(1.2)	(-3.1)
SS (kt)	**-4.5**	4.4	-8.9
	(-1.2)	(1.2)	(-2.4)

Source: Authors' model results.

Table 4: Percentage changes in resource-sector output levels in various regions of the world following Uruguay Round trade reform (including China), 2010

	Indonesia	***Other APEC developing economies***	***Other developing & transition economies***	***APEC high-income economies***	***Other high-income economies***	***Total world***
Paddy rice	-0.3	2.9	-1.3	-1.0	-3.1	**0.48**
Non-grain crops	-4.6	4.3	-0.4	2.0	-2.9	**0.59**
Livestock	0.1	-1.4	-1.6	0.9	1.2	**-0.06**
Forestry	-1.1	-0.7	-0.1	-0.0	1.9	**-0.03**
Fisheries	-0.7	-7.4	0.1	-0.4	5.1	**-0.21**
Coal	-7.1	-0.6	0.2	-0.3	1.0	**0.03**
Oil	-3.3	-2.9	0.2	0.1	0.4	**-0.04**
Gas	-3.4	-1.4	0.1	0.5	0.1	**0.06**
Other minerals	-5.2	-5.0	-0.7	-1.4	1.9	**-0.39**

Source: Authors' model results.

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