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ABSTRACT

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Most-favoured-nation (MFN) trade liberalizations will always improve global economic welfare provided globally optimal environmental and other policies are in place. But since the latter proviso is not met in practice, empirical studies of the environmental and resource depletion effects of such reforms are needed to convince sceptics that trade reform is still worthwhile. This paper provides a methodology for doing that. It is illustrated with a case study of 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 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, 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, and even if the reforms stimulate a faster rate of economic growth.

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

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

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NON-TECHNICAL SUMMARY

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. 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 the question of whether liberalizing trade between rich and poor countries is desirable. To reduce the risk that this concern leads to excessive opposition to trade liberalization initiatives, empirical studies of the environmental and resource depletion effects of such reforms are needed.

This paper provides a methodology for doing that. It is illustrated with a case study of 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. (This long-run view allows us to abstract from the (hopefully only short-run) disruptions of the current financial and political crisis.) 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 (a) full global implementation of Uruguay Round commitments by 2010, and (b) the additional move to MFN free trade by APEC countries by 2020. The paper concludes with a summary of results and suggestions for further research.

The main conclusion from this case study of Indonesia is that, at least with respect to air and water, 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, and even if the reforms stimulate a faster rate of economic growth. In particular, the damage that trade liberalization might cause is estimated to be only a tiny fraction of the damage that normal economic growth and structural change would cause by 2020 if trade and environmental policies did not change. The conventional economic gains from the trade reforms and the scope for adopting well-targeted environmental policies to reduce any serious damage are such that social welfare almost certainly is going to be improved substantially by these liberalizations to which Indonesia and many other countries are committed.

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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 reduce the risk that this concern leads to excessive opposition to trade liberalization initiatives, and to begin to assess whether the standard gains from trade are sufficient to outweigh any loss in welfare due to added environmental damage, empirical studies of the resource depletion and environmental degradation effects of such reforms are needed.

This paper provides a methodology for doing that and illustrates it with a case study of 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. 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 (hopefully only short-run) 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 without trade reform 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 a brief summary of results and suggestions for further research.

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. In this section 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 happens to be the end of Indonesia's Second Long Term Development Plan.

For the present purpose of projecting the world economy to 2020 we use the GTAP database and model of national and international markets for all products and countries/regions of the world (see Hertel 1997). 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.

World Bank GDP, labor force, investment and population projections together with the Global Trade Analysis Project (GTAP) Version 3 data base and model are used to generate market projections to the year 2020. The full GTAP model divides the world economy up 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, however, the data base is aggregated up to 23 product groups and to 5 regions in addition to Indonesia.

The GTAP model is a standard comparative-static multi-region computable general equilibrium model of the Johansen type that began as the SALTER model developed by the Australian Government in the 1980s but has been hugely improved during the 1990s from its current home at Purdue University in the United States. The model, which is implemented and solved using GEMPACK (Harrison and Pearson 1996), is in use by over one hundred researchers in more than 30 countries on five continents. Hence space is not used here to describe its myriad features and data base.[1]

The model utilizes a representation of consumer demands which allows for differences in both the price and income responsiveness of demand in different regions depending upon both the level of development of the region and the particular

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

consumption patterns observed in that region. In the simulations presented below, many of the East Asian economies are projected to continue to experience very rapid economic growth rates (assuming a reasonably rapid recovery from the present financial crisis), so that the income elasticities of demand play an important role in the model. Non-homothetic preferences are captured through use of a constant difference of elasticities (CDE) function. This falls between the nonhomothetic constant elasticities of substitution (CES) function, which is commonly used in CGE models, and fully flexible functional forms (Hertel 1997). This demand system enables non-homothetic demand to be calibrated to replicate a pre-specified vector of own-price and income elasticities of demand.

On the supply-side, differences in relative rates of factor accumulation interact with different sectoral factor intensities to drive changes in the sectoral composition of output. The GTAP production system used here distinguishes sectors by their intensities in four primary factors of production: natural resources, unskilled labor, skilled labor, and physical capital. Thus in a region where physical capital is accumulating rapidly, relative to other factors, we expect the capital intensive sectors to expand at the expense of unskilled labor intensive sectors such as agriculture in East Asia. Producers are assumed to choose inputs that minimize production costs subject to separable, constant returns to scale technologies. Constant elasticity of substitution (CES) functions describe substitution possibilities between primary factors and market clearing conditions equate supply with demand for each factor of production. For intermediate inputs, the assumption of a Leontief function implies no substitution between different intermediates or between them and a composite primary factor.

Land and other natural resources (minerals and energy raw materials) are assumed to be sector-specific in this study, except that some movement of land within agricultural sectors and between agriculture and forestry is allowed. It is assumed that 60 per cent of value added by capital in each of the natural resource sectors is attributable to the specific factor (see Strutt (1998, Chs. 3 and 4) for details). The single factor labour in GTAP is split into skilled and unskilled labour for this study, whereby the global GTAP database is adjusted using recent estimates of labour payments by skill level (Liu et al. 1997, p. 17). A composite capital nest is created for human and physical capital, following Arndt et al. (1997).

The present paper follows the methodology used in Hertel et al. (1996) and Anderson and Pangestu (1998) but projects the world economy from 1992 not just to 2005 but to 2010 before looking at the long-run effects of Uruguay Round trade policy reforms to be implemented between now and 2005. It does the same from 2010 to 2020, to get a more realistic measure of the long-run effects of APEC reforms. 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).

Table 1 reports the assumed rates of growth in factors and real GDP (from which the implied rates of total factor productivity growth may be derived) in the reference case for the periods from 1992 to 2010 and 2010 to 2020. Exogenous projections of each region’s endowments of physical capital, unskilled and skilled labor, and population are utilized. These are based on combinations of historical data and World Bank projections of the growth in population, labor force, real GDP and investment.[2] It is clear from these estimates that the structure of the world economy will change in a number of important ways in this base case, with the developing countries constituting a considerably larger share of the global economy by 2020. Furthermore, given the particularly high rates of savings and investment in East Asia, the capital-labor ratios of these economies are expected to increase, creating supply-side pressures for changes in the composition of output in these economies (Krueger 1977; Leamer 1987). The relatively high rates of accumulation of human capital in developing economies also are likely to contribute to pressures for structural change as developing countries upgrade the skill-intensity of their product mix. Taking all these things into account and starting with the 1992 baseline, the model generates projections of the world economy assuming no changes to existing trade and other policies. That base scenario is then compared with scenarios involving trade policy reforms.

For Indonesia, the assumed rates of factor and GDP growth are close to government expectations and are in line with past trends. Over the 13 years from 1980, for example, the population and labor force growth rates were a little higher than those being projected here for the 18 years to 2010 (1.7 and 2.3 per cent historically compared with assumed rates of 1.4 and more than 2.0 in Table 1), while the rates of growth of physical capital and real GDP were a little lower than those projected here (7.1 and 5.8 per cent historically compared with assumed rates of 7.4 and 6.6 in Table 1).

The model can be closed with either gross domestic product (GDP) or total factor productivity (TFP) as exogenous targets. Since projections for GDP are available, these are imposed on the model, while total factor productivity is endogenized. Empirical evidence suggests that agriculture has a higher total factor productivity growth rate than other sectors (see Martin and Mitra 1996). Therefore, the assumption made here is that agricultural productivity increases at a rate of 0.7 per cent per annum higher than other sectors.

With these and myriad other assumptions including those incorporated in the GTAP model (see Strutt 1998, Ch. 4 for details), 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 first excluded but then included in the WTO (the main difference being whether China is excluded or included in getting expanded access to US and EU textile and clothing markets -- see Anderson et al. 1997); and then with APEC liberalization commitments also being implemented by 2020. The scenario for 2010 with the Uruguay 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. Indonesia's nominal rates of import protection for each sector at the beginning of each of these reform scenarios are shown in Appendix Table A.

[2] Growth rates for 1992-2010 are adapted from Anderson et al. (1997) and Arndt et al. (1997), while growth rates for 2010-2020 are adapted from Bach (1997).

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. The latter are summarized in Table 2. It shows Indonesia's agricultural and other natural resource based sectors continuing 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 (columns 5 and 6) – even though the absolute level of output keeps rising in these as in all other sectors (columns 3 and 4). Another example is that 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. Table 3 shows, for example, how much additional impact by 2010 the Uruguay Round's implementation would have on the output of different sectors in Indonesia, both without and then with China included, and then how much extra impact the APEC reforms to 2020 would add. Since liberalization is expected to raise GDP growth rates as well,[3] we also simulate the APEC reform assuming each APEC economy's annual GDP growth rate over the 20-year implementation period (2000 to 2020) is half a percentage point higher than in the base case, due to faster total factor productivity growth. 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 (compare Tables 2 and 3). 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 (or 1.9 per cent if China were to be excluded), and the APEC reform (to 2020) 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

[3] See, for example, the theoretical reasons presented in Grossman and Helpman (1991), and the rapidly growing empirical evidence presented by Baldwin (1992), Dollar (1992), Edwards (1992), Sachs and Warner (1995), Harrison (1996), and USITC (1997) and the references therein.

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.

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

[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. There have also been attempts to incorporate environmental equations and parameters more directly into a CGE model (for example, Xie 1996).

[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.

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.[6] Define the total change in pollution (P) as the sum of the changes in pollution in each sector $\left(P_j\right)$:

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

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

[6] 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, 1998). Beghin et al. (1997, 1998) also discuss such a three-way decomposition.

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. 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 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 2 shows the 1992 and projected 2010 output levels for each sector, evaluated at 1992 prices, and 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. Table 4 lists the initial 1992 level and projected new levels of emissions for 2010 without the Uruguay Round or APEC being implemented, and 2020 after the Round's implementation but without APEC trade reform. Large increases are projected for all of these air pollutants. Since the Indonesian economy is projected to grow by 215 per cent between 1992 and 2010 and a by further 95 per cent by 2020, this finding is not surprising. 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 5 decomposes these air pollution effects to give a more precise 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 technique effect which is negative for all air pollutants in Table 5, reflecting the improved technologies expected to become available.

Water use and pollution

Table 6 presents water use and water pollution results, calculated for the various sectors using GTAP simulation results and a water use and pollution side module.[7] 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. However increases in water use are dwarfed by

[7] Increases in household water use are taken from estimates in Duchin et al. (1993) and entered exogenously, assuming Indonesia's population increases to 263 million by 2020.

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 5). The decomposition in Table 5 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 5(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.

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? The first two columns of Table 3 show the proportional change in output due to Uruguay Round liberalization, first without and then with the inclusion of China as a WTO member. The second pair of columns show the projected sectoral changes in output due to APEC liberalization. Leaving aside the final scenario in which economic growth is assumed to be boosted by APEC liberalization (discussed separately below), some sectors reduce and other sectors increase their output level because of trade reform, in contrast to the middle columns of Table 2 for structural change projections where all sectors increase their output. We therefore can expect the composition effects to be much stronger relative to the aggregate activity effects in these reform cases, in contrast to the growth and structural change scenarios discussed above.

The results in Table 3, 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 a 60 per cent boost to output anticipated if China is kept out of the WTO, or just under 40 per cent if China is able to join. 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 7 indicates that a *reduction* in air pollution is projected for Indonesia under Uruguay Round liberalization (including China), 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 7 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 examined by sector (Table 8), 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 is not included in the WTO and hence by assumption does not liberalize its trade, the reductions in Indonesia's air pollution almost double relative to the reductions shown in Table 7 when China is included. 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.[8]

With additional APEC trade liberalization, air pollution is projected to increase but, as shown in Table 9, the increases are only between 2 and 4 per cent. Moreover, a

[8] 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).

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 9). 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, as can be seen by the numbers in square parentheses in Tables 7 and 9.

Water use and pollution

Water withdrawals are reduced by both trade liberalizations. Table 7 shows a reduction in withdrawals of 0.3 per cent with Uruguay Round implementation, while Table 9 shows that water withdrawals reduce by a further 1.6 per cent with APEC liberalization. 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 7. 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 9 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.

What if trade reform boosts economic growth?

The above simulations of trade reform are from a comparative static model and so do not include the impact that trade reform would have in boosting economic growth. Hence it understates the extent of pollution that might result. To get a feel of how large that bias might be, we re-ran the APEC liberalization but assumed that APEC economies' GDPs would grow substantially faster (by half a percentage point per year over the 20-year implementation period to 2020) through a boost to their total factor productivity growth. The impact of APEC reform including that faster growth on the pollution results is shown in Table 10, based on the output effects summarized in the final column of Table 3. Not surprisingly, that change in assumption raises the effect of liberalization on pollution. Even so, the numbers are small: air pollution is 12-15 per cent greater and water pollution 6-12 percent greater, than would have been the case in 2020 (instead of no more than 4 per cent as when we assume no growth effect of APEC reform). This amount is less than one fifth of the air pollution (and a somewhat larger fraction of the water pollution) that would result from the normal output expansions and structural changes that would take place without reform. Moreover, that extra pollution due to accelerated growth is accompanied by a much greater boost to economic welfare as conventionally measured than when we assume there is no growth effect of trade reform: Indonesia's GDP in 2020 is 10.8 per cent higher in this growth-enhancing case, compared with only 1.2 per cent higher in the earlier APEC reform case that assumed no growth effect. Clearly this compensates generously for the extra pollution and provides great scope for spending some of that extra income on pollution abatement.

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 11 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. Of course there are some offsetting changes in other economies, but the final column of Table 11 shows that in aggregate the changes to natural resource use from the Round will be tiny.

4. Conclusions

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 so as 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 is necessarily the case that economic growth enhances social welfare. That may not preclude a worsening of environmental degradation or further 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 so 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 therefore 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.[9]

This case study of Indonesia suggests that trade policy reforms slated for the next two decades in most 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

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

resource depletion even without toughening the enforcement of existing environmental and resource regulations or adding new ones. 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 substantially by these liberalizations.[10]

Furthermore, a related study (Strutt 1998, Ch. 3) which focuses on land degradation through soil erosion and associated off-site damage draws a similar conclusion. That study incorporates feedback effects of that damage on land productivity and thereby is able to value the loss of production associated with that erosion. Again using GTAP to model the effects of implementing the Uruguay Round agreements, the study finds that the aggregate output expansion and shift in its composition does add slightly to soil erosion, but that the cost of the damage caused by that increased erosion is miniscule, amounting to less than 0.2 per cent of the national economic welfare gain (as traditionally measured) from the Uruguay Round liberalization.

Moreover, this study has focused only on one country's resources and environment. The natural resource impact of the Uruguay Round can be seen in Table 11 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. And it happens that when environmental damage occurs in Indonesia because of the change in the composition of its output following trade reform, damage to the environment of other countries is often lessened. A case in point 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: the above results show 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 moves away from some of its very pollutive coal-intensive heavy manufacturing, thereby potentially reducing not only local pollution but also global warming. The latter could be quantified by extending the environmental side modules developed here for Indonesia to other countries and regions of the world included in the GTAP model.[11]

Needless to say, caution should be used in interpreting the above results, particularly given the still poor quality of environmental data. The results presented

[10] This is not inconsistent with the finding by Lindert (1996) that there is virtually no evidence over many decades of net soil degradation in Indonesia.

[11] A new paper by Cole, Rayner and Bates (1997) applies emission coefficients to another set of Uruguay Round output results using GTAP for the world as a whole and places monetary values on the estimated changes in 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 new empirical study, by Unteroberdoerster (1998), looks at APEC trade liberalization alone and again finds very small effects on the environment.

here indicate sectors of particular concern, given available information. However, there are other sectors and types of environmental damage that are not adequately represented here.[12] Clearly, this kind of research is in its infancy; there are many future directions and areas where improvements can be made. For example, as improved environmental data becomes available for other regions, the environmental effects in other countries could be traced. More-direct inclusion of emissions and abatement activities in the GTAP model may be desirable too, rather than having just side modules. 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,[13] trade policy changes and changes in pollution would be another useful extension. But that is all for another day.

[12] For example, the most excessive pollutant in Indonesian rivers is faecal coliform which exceeds recommended standards by more than a thousandfold in some places (World Bank 1990, p. xxxi). We have not been able to include this in our present analysis. Nor have we accounted for the human health effects of pollution (as was done for Chile in Beghin et al. 1998).

[13] 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, Seldon and Song (1994), Grossman and Krueger (1995), and Hettige, Mani and Wheeler (1998).

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Table 1: Assumptions made in the projections: cumulative [and annual] percentage changes in GDP and factor endowments for the period 1992 to 2020

(a) 1992-2010

Region	*Real GDP*	*Physical capital*	*Unskilled labour*	*Skilled labour*	*Population*
Indonesia	215 [6.6]	260 [7.4]	44 [2.0]	449 [9.9]	27 [1.4]
Other APEC developing economies	202 [6.3]	312 [8.2]	26 [1.3]	167 [5.6]	19 [1.0]
Other developing and transition economies	73 [3.1]	61 [2.7]	43 [2.0]	151 [5.3]	40 [1.9]
APEC high-income economies	66 [2.9]	101 [4.0]	16 [0.8]	150 [5.2]	16 [0.8]
Other high-income economies	55 [2.5]	53 [2.4]	1 [0.1]	394 [9.3]	3 [0.2]

(b) **2010-2020**

Region	*Real GDP*	*Physical capital*	*Unskilled labour*	*Skilled labour*	*Population*
Indonesia	95 [6.9]	135 [8.9]	17 [1.6]	77 [5.9]	14 [1.3]
Other APEC developing economies	72 [5.6]	88 [6.5]	9 [0.9]	51 [4.2]	9 [0.8]
Other developing and transition economies	49 [4.1]	46 [3.9]	29 [2.6]	62 [5.0]	18 [1.7]
APEC high-income economies	27 [2.5]	47 [3.9]	3 [0.3]	53 [4.3]	7 [0.7]
Other high-income economies	28 [2.5]	34 [3.0]	-4 [-0.4]	79 [6.0]	0 [0.0]

Source: Strutt (1998, Ch.4) drawing on Anderson et al. (1996), Arndt et al. (1997) and, for 2010-2020, Bach (1997).

Table 2: Percentage changes in sectoral output levels and in sectoral shares of GDP due to economic growth, Indonesia, 1992-2010 and 2010-2020[a]

Sector	*1992 output (US$b)*	*2010 output (US$b)*	*Change in real value of output, 1992-2010 (%)*	*Change in real value of output, 2010-2020 (%)*	*Change in sectoral share of GDP, 1992-2010 (%)*	*Change in sectoral share of GDP, 2010-2020 (%)*
Paddy rice	7.5	14.1	87	35	-41	-31
Other grains	0.8	1.0	23	1	-61	-48
Non-grain crops	12.4	19.5	58	15	-50	-41
Livestock	3.2	6.9	113	36	-32	-30
Forestry	2.5	5.1	100	43	-36	-26
Fisheries	3.8	7.0	85	23	-41	-37
Coal	0.8	1.8	124	49	-29	-23
Oil	7.4	15.8	114	64	-32	-16
Gas	6.1	12.4	103	59	-36	-18
Other minerals	3.1	7.1	131	82	-27	-7
Food processing	24.0	44.7	87	34	-41	-31
Textiles, clothing, leather	14.1	77.4	449	177	74	42
Wood products	7.2	12.5	73	32	-45	-32
Paper products	2.7	11.7	331	132	37	19
Petroleum & coal products	5.3	18.8	253	121	12	13
Chemicals, rubber & plastics	9.4	35.8	282	120	21	13
Non-metallic mineral products	1.9	6.8	267	125	17	15
Other manufactured products	20.0	95.0	375	201	51	55
Electricity, water & gas	2.8	10.2	268	118	17	12
Construction	22.1	75.4	241	125	8	16
Trade & transport	25.0	101.0	304	120	28	13
Other private services	36.2	142.5	293	114	25	10
Other public services	8.6	46.9	447	61	74	-18
Total, all sectors	**227.0**	**769.5**	**215**	**95**		

[a] The projections for the period to 2010 maintain initial protection data, while those for the period 2010 to 2020 in columns 5 and 7 assume that the Uruguay Round, including China, has been fully implemented by 2010.

Source: GTAP V3 database and authors' model results.

Table 3: Percentage changes in sectoral output levels in Indonesia following Uruguay Round and APEC trade reform by 2010 and 2020

	Uruguay Round (without China), 2010	**Uruguay Round (with China), 2010**	**APEC liberal-ization, 2020**	**APEC liberal-ization, 2020** (with extra GDP growth of 0.5% pa in APEC economies)
Paddy rice	-0.6	-0.3	-1.6	5.9
Other grains	3.2	4.7	14.9	22.6
Non-grain crops	-5.1	-4.6	-13.4	-4.5
Livestock	-0.2	0.1	3.1	13.2
Forestry	-3.4	-1.1	-0.2	9.4
Fisheries	-1.1	-0.7	-4.1	5.8
Coal	-12.1	-7.1	18.4	31.1
Oil	-5.4	-3.3	0.6	11.9
Gas	-5.4	-3.4	0.7	11.1
Other minerals	-8.1	-5.2	-1.6	8.3
Food processing	-0.6	-0.3	-1.7	5.8
Textiles, clothing, leather	61.9	38.5	-2.6	2.9
Wood products	-6.9	-2.4	1.2	11.5
Paper products	-7.8	-3.7	6.7	17.8
Petroleum & coal products	0.9	0.5	-2.1	7.0
Chemicals, rubber & plastics	1.1	2.5	9.2	20.8
Non-metallic mineral products	-7.5	-4.4	23.8	33.6
Other manufactured products	-19.6	-12.3	-1.9	7.4
Electricity, water & gas	2.5	1.5	1.1	10.7
Construction	0.5	-0.1	-1.5	5.9
Trade & transport	-2.4	-1.3	4.9	16.3
Other private services	-2.0	-1.4	1.3	12.1
Other public services	-0.6	-0.5	-1.0	9.3
Real GDP growth	**1.9**	**1.4**	**1.2**	**10.8**

Source: Authors' model results.

Table 4: Recent and projected levels of atmospheric emissions in the base cases, Indonesia, 1992, 2010, and 2020[a] (kt)

	1992			*2010*			*2020*		
	carbon	***sulphur***	***nitrogen***	***carbon***	***sulphur***	***nitrogen***	***carbon***	***sulphur***	***nitrogen***
Paddy rice	1	0.0	0.1	2	0.0	0.1	3	0.0	0.2
Other grains	16	0.0	0.9	20	0.0	1.1	21	0.0	1.2
Non-grain crops	241	0.3	14.0	378	0.5	22.0	415	0.5	24.2
Livestock	310	0.4	17.9	677	0.8	39.1	931	1.1	53.8
Forestry	246	0.3	14.4	485	0.6	28.3	682	0.8	39.8
Fisheries	531	0.6	31.1	882	1.1	51.6	1,014	1.2	59.3
Coal	853	25.2	5.8	956	28.2	6.5	589	17.4	4.0
Oil	4,463	53.4	31.1	9,187	109.9	64.0	14,244	170.3	99.2
Gas	4,096	0.8	39.2	6,129	1.2	58.7	7,549	1.5	72.3
Other minerals	409	11.1	1.5	650	17.6	2.4	837	22.7	3.1
Food processing	489	13.0	1.8	752	19.9	2.8	890	23.5	3.3
Textiles, clothing, leather	293	7.7	1.1	770	20.1	3.0	1,160	29.9	4.6
Wood products	481	12.9	1.8	880	23.6	3.2	1,167	31.3	4.2
Paper products	217	6.3	1.5	712	20.8	5.0	1,317	38.9	9.7
Petroleum & coal products	1,305	17.4	8.3	4,047	54.4	25.7	8,302	112.4	52.8
Chemicals, rubber & plastics	3,330	35.6	26.6	5,930	65.9	47.3	4,867	60.8	38.6
Non-metallic mineral products	894	25.6	5.4	2,503	73.0	16.8	4,448	131.9	32.5
Other manufactured products	880	23.0	3.4	1,997	52.0	7.8	2,074	53.5	8.2
Electricity, water & gas	7,843	168.2	102.8	18,045	347.1	241.6	26,637	434.2	366.8
Construction	10,547	69.2	37.9	25,007	164.1	89.9	42,587	279.5	153.1
Trade & transport	10,322	129.8	532.5	30,564	384.5	1,578.4	52,865	665.4	2733.0
Other private services	193	1.2	0.8	559	3.4	2.2	943	5.7	3.7
Other public services	709	4.1	2.8	2,882	16.8	11.4	3,724	21.6	14.8
Total, all sectors	**48,668**	**606**	**882**	**114,014**	**1,405**	**2,309**	**177,264**	**2,104**	**3,782**

Source: Authors' model results.

[a] 2020 levels include Uruguay Round implementation.

Table 5: 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 6: Recent and projected levels of water use and quality in the base cases, Indonesia, 1992, 2010, and 2020[a]

Base level for 1992	*Water in (millions of m^3)*	*Water out (millions of m^3)*	*BOD (kt)*	*COD (kt)*	*Dissolved solids (kt)*	*Suspended solids (kt)*
Paddy rice	313,072	0	0	0	0	0
Livestock	8	0	0	0	0	0
Food processing	124	97	21	30	37	49
Textiles, clothing, leather	102	102	18	72	0	87
Paper products	217	97	64	217	0	70
Chemicals, rubber, plastics	5	4	0	0	0	0
Other manufactures	307	307	54	216	0	261
Households	10,704	0	0	0	0	0
Total, all sectors	**324,538**	**608**	**157**	**534**	**37**	**466**

2010	*Water in (millions of m^3)*	*Water out (millions of m^3)*	*BOD (kt)*	*COD (kt)*	*Dissolved solids (kt)*	*Suspended solids (kt)*
Paddy rice	300,439	0	0	0	0	0
Livestock	16	0	0	0	0	0
Food processing	132	104	12	17	20	24
Textiles, clothing, leather	278	278	32	127	0	129
Paper products	519	262	111	402	0	83
Chemicals, rubber, plastics	9	9	0	0	0	0
Other manufactures	720	720	82	329	0	334
Households	15,712	0	0	0	0	0
Total, all sectors	**317,825**	**1,372**	**238**	**875**	**20**	**571**

2020	*Water in (millions of m^3)*	*Water out (millions of m^3)*	*BOD (kt)*	*COD (kt)*	*Dissolved solids (kt)*	*Suspended solids (kt*
Paddy rice	190,557	0	0	0	0	0
Livestock	21	0	0	0	0	0
Food processing	104	82	5	7	7	7
Textiles, clothing, leather	460	460	37	147	0	115
Paper products	645	390	115	449	0	37
Chemicals, rubber, plastics	11	10	0	0	0	0
Other manufactures	822	822	65	263	0	206
Households	18,494	0	0	0	0	0
Total, all sectors	**211,114**	**1,764**	**223**	**866**	**7**	**365**

Source: Authors' model results.
[a] 2020 levels include Uruguay Round implementation.

Table 7: Decomposition of pollution effects from Uruguay Round trade reform (including in China), Indonesia, 2010 (% change from 2010 baseline level shown in curved parentheses, % of the 1992-2010 absolute change is in square parentheses)

	Total change	**Aggregate activity**	**Intersectoral composition**
Carbon (kt)	**-733**	1,585	-2,318
	(-0.6)	(1.4)	(-2.0)
	[-1.1]	[2.4]	[-3.5]
Sulphur (kt)	**-8**	20	-27
	(-0.6)	(1.4)	(-1.9)
	[-1.0]	[2.4]	[-3.4]
Nitrogen (kt)	**-22**	32	-54
	(-1.0)	(1.4)	(-2.3)
	[-1.5]	[2.2]	[-3.8]
Water in (billion m^3)	**-0.8**	4	-5
	(-0.3)	(1.4)	(-1.6)
	[-7]	[35]	[-42]
Water out (billion m^3)	**0.01**	0.02	-0.01
	(0.6)	(1.4)	(-0.8)
	[1.1]	[2.4]	[-1.3]
BOD (kt)	**-2.0**	3	-5
	(-0.9)	(1.4)	(-2.3)
	[-2.5]	[4.1]	[-6.6]
COD (kt)	**-6.5**	12	-19
	(-0.7)	(1.4)	(-2.1)
	[-1.9]	[3.6]	[-5.5]
DS (kt)	**-0.05**	0.3	-0.3
	(-0.3)	(1.4)	(-1.7)
	[-0.3]	[1.6]	[-2.0]
SS (kt)	**5.3**	8	-3
	(0.9)	(1.4)	(-0.5)
	[5.0]	[7.6]	[-2.5]

Source: Authors' model results.

Table 8: Sectoral decomposition of the total change in emissions due to Uruguay Round implementation, Indonesia, 2010

	Carbon (kt)	*Sulphur (kt)*	*Nitrogen (kt)*	*Water in (bm^3)*	*Water out (bm^3)*	*BOD (kt)*	*COD (kt)*	*DS (kt)*	*SS (kt)*
Paddy rice	-0.01	0.00	0.00	-0.78	0.00	0.00	0.00	0.00	0.00
Other grains	0.93	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Non-grain crops	-17.33	-0.02	-1.01	0.00	0.00	0.00	0.00	0.00	0.00
Livestock	0.95	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	-5.09	-0.01	-0.30	0.00	0.00	0.00	0.00	0.00	0.00
Fisheries	-6.35	-0.01	-0.37	0.00	0.00	0.00	0.00	0.00	0.00
Coal	-67.89	-2.00	-0.46	0.00	0.00	0.00	0.00	0.00	0.00
Oil	-301.33	-3.60	-2.10	0.00	0.00	0.00	0.00	0.00	0.00
Gas	-207.77	-0.04	-1.99	0.00	0.00	0.00	0.00	0.00	0.00
Other minerals	-33.86	-0.92	-0.13	0.00	0.00	0.00	0.00	0.00	0.00
Food processing	-2.03	-0.05	-0.01	0.00	0.00	-0.03	-0.05	-0.05	-0.07
Textiles, clothing, leather	296.17	7.71	1.15	0.11	0.11	12.20	48.81	0.00	49.57
Wood products	-21.47	-0.58	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
Paper products	-26.13	-0.76	-0.18	-0.02	-0.01	-4.08	-14.74	0.00	-3.05
Petroleum & coal products	21.45	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Chemicals, rubber & plastics	150.03	1.67	1.20	0.00	0.00	0.00	0.00	0.00	0.00
Non-metallic mineral products	-108.88	-3.17	-0.73	0.00	0.00	0.00	0.00	0.00	0.00
Other manufactured products	-246.05	-6.40	-0.96	-0.09	-0.09	-10.14	-40.55	0.00	-41.18
Electricity, water & gas	276.08	5.31	3.70	0.00	0.00	0.00	0.00	0.00	0.00
Construction	-27.51	-0.18	-0.10	0.00	0.00	0.00	0.00	0.00	0.00
Trade & transport	-385.10	-4.84	-19.89	0.00	0.00	0.00	0.00	0.00	0.00
Other private services	-7.71	-0.05	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
Other public services	-13.83	-0.08	-0.05	0.00	0.00	0.00	0.00	0.00	0.00
Total, all sectors	**-732.75**	**-7.74**	**-22.09**	**-0.78**	**0.01**	**-2.05**	**-6.53**	**-0.05**	**5.27**

Source: Authors' model results.

Table 9: Decomposition of pollution effects in Indonesia under APEC liberalization, 2020 (% change from 2020 baseline level shown in curved parentheses, % of the 1992-2020 absolute change is in square parentheses)

	Total change	**Aggregate activity**	**Intersectoral composition**
Carbon (kt)	**3,736**	2,124	1,612
	(2.1)	(1.2)	(0.9)
	[2.9]	[1.6]	[1.3]
Sulphur (kt)	**72**	25	47
	(3.4)	(1.2)	(2.2)
	[4.8]	[1.7]	[3.1]
Nitrogen (kt)	**144**	45	99
	(3.8)	(1.2)	(2.6)
	[4.9]	[1.6]	[3.4]
Water in (billion m^3)	**-3.0**	2.3	-5.3
	(-1.6)	(1.2)	(-2.8)
	[-2.5]	[1.9]	[-4.4]
Water out (billion m^3)	**-0.002**	0.02	-0.02
	(-0.1)	(1.2)	(-1.3)
	[-0.2]	[1.8]	[-1.9]
BOD (kt)	**5.4**	2.7	2.7
	(2.4)	(1.2)	(1.2)
	[7.9]	[3.9]	[4.0]
COD (kt)	**21.1**	10.4	10.8
	(2.4)	(1.2)	(1.2)
	[6.2]	[3.0]	[3.2]
DS (kt)	**-0.13**	0.09	-0.21
	(-1.8)	(1.2)	(-3.1)
	[-0.4]	[0.3]	[-0.7]
SS (kt)	**-4.5**	4.4	-8.9
	(-1.2)	(1.2)	(-2.4)
	[-4.2]	[4.1]	[-8.4]

Source: Authors' model results.

Table 10: Decomposition of pollution effects in Indonesia under APEC liberalization, with 0.5% p.a. extra GDP growth in APEC economies, 2020 (% change from 2020 baseline level shown in curved parentheses, % of the 1992-2020 absolute change is in square parentheses)

	Total change	Aggregate activity	Intersectoral composition
Carbon (kt)	**21,142**	19,091	2,051
	(12)	(11)	(1)
	[16]	[15]	[2]
Sulphur (kt)	**283**	227	57
	(14)	(11)	(3)
	[19]	[15]	[4]
Nitrogen (kt)	**557**	407	149
	(15)	(11)	(4)
	[19]	[14]	[5]
Water in	**11**	21	-9
(billion m^3)	**(6)**	(11)	(-5)
	[9]	[17]	[-8]
Water out	**0.15**	0.19	-0.04
(billion m^3)	**(9)**	(11)	(-2)
	[13]	[16]	[-3]
BOD (kt)	**27**	24	3
	(12)	(11)	(1)
	[39]	[35]	[4]
COD (kt)	**104**	93	11
	(12)	(11)	(1)
	[31]	[28]	[3]
DS (kt)	**0.4**	0.8	-0.4
	(6)	(11)	(-5)
	[2]	[3]	[-1]
SS (kt)	**26**	39	-14
	(7)	(11)	(-4)
	[24]	[37]	[-13]

Source: Authors' model results.

Table 11: 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.

Appendix Table A: Import tariff rates in Indonesia without and with Uruguay Round liberalization, by sector, 2010 (per cent)

	2010 base	2010 after UR
Paddy rice	9.0	9.0
Other grains	0.0	0.1
Non-grain crops	54.7	38.3
Livestock	4.8	4.8
Forestry	14.4	14.4
Fisheries	29.8	29.8
Coal	5.0	5.0
Oil	0.0	0.0
Gas	5.0	5.0
Other minerals	4.9	4.9
Food processing	12.3	11.3
Textiles, clothing, leather	28.7	22.5
Wood products	34.4	31.0
Paper products	8.0	8.0
Petroleum & coal products	4.7	4.7
Chemicals, rubber & plastics	6.6	6.6
Non-metallic mineral products	14.1	12.9
Other manufactured products	15.6	15.4
Electricity, water & gas	0.0	0.0
Construction	0.0	0.0
Trade & transport	0.0	0.0
Other private services	0.0	0.0
Other public services	0.0	0.0

Source: GTAP data base and authors’ model results.