



ECONOMIC GROWTH, TRADE POLICY AND THE ENVIRONMENT IN INDONESIA

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ABSTRACT

Economic Growth, Trade Policy and the Environment in Indonesia

Anna Strutt

Economic growth is often perceived to impose high-cost environmental damage, especially in developing countries where property rights and other environmental and resource policies are poorly developed. Market reforms such as trade liberalization are seen by some groups as adding to environmental damage through boosting income growth and structural change. Yet others claim that such policy changes may have positive impacts on the natural environment. This thesis examines these conflicting claims both theoretically and empirically, with Indonesia as a case study.

The thesis contributes to the theoretical literature on growth-environment interactions with a dynamic model that explicitly takes environmental damage and production feedback effects into account. It suggests that policy changes which raise growth, such as trade liberalization, may have ambiguous effects on the natural environment.

The other contribution of the thesis is to the empirical literature. To help determine the direction and magnitude of the effects on Indonesia's environment, a global computable general equilibrium model is used. Initially the analysis concentrates on land degradation in agriculture, where it includes feedback effects on farm production. We then project the world economy to 2010 and 2020 to examine, for all sectors of the Indonesian economy, the air and water pollution effects of structural changes. The analysis looks first at the effects of continued rapid economic growth and then at trade policy reform.

We find that Uruguay Round implementation is likely to lead to an increase in net erosion of soil and associated off-site damage in Indonesia. However, this increase is extremely small. Furthermore, we find that the trade liberalizations slated for the next two decades will in many cases improve air and water pollution levels. Even in the worst cases, the environmental 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. The economic gains from trade reform are almost certain to be judged to more than compensate for the risk of increased environmental damage, especially since some of those proceeds can be spent on well-targeted environmental policies aimed at mitigating such damage.

STATEMENT OF AUTHORSHIP

This work contains no material which has been accepted for the award of any degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Anna Strutt

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1. INTRODUCTION¹

1.1 Market liberalization, economic growth and the environment

Economic growth is often perceived to impose high-cost environmental damage on present and future generations. Developing countries are a particular concern where inadequate property rights combine with low-income, poorly educated and rapidly growing populations whose views may not be reflected in government policy. Some groups argue that market reforms, such as trade liberalization, may have large and adverse effects on the natural environment (for example Reed 1998). Others claim that such policy changes may in fact have positive impacts on the natural environment. This thesis examines the conflicting claims, both theoretically and empirically, with Indonesia as a case study. The relative contributions to environmental damage of both structural change and trade reform are assessed.

The theory section (Chapter Two) examines the relationship between economic growth and environmental services. It contributes to the theoretical literature on growth-environment interactions with a dynamic model of those interactions, a model that explicitly takes adverse feedback effects on production into account.

¹ This chapter draws on Strutt (1995) and Anderson and Strutt (1996).

The empirical section (Chapters 3-5) quantifies the environmental effects of altered incentives in a large and rapidly developing country, namely Indonesia. Incentives are altered either because of economic growth or because of policy reforms. To help determine the direction and magnitude of the effects of those economic changes on Indonesia's environment, an available global computable general equilibrium model is modified for the purpose at hand. Initially the analysis concentrates on land degradation in agriculture. We model environmental impacts, including feedback effects on production, together with the standard intersectoral impacts of economic policy reforms. We use a specially adapted version of the model to project the world economy to 2010 and 2020. We use this to examine for all sectors the air and water pollution effects first of expected economic growth and structural change and then of planned trade reforms in Indonesia. Two sets of trade reforms are considered: implementation over next few years of Uruguay Round commitments by Indonesia and all other members of the World Trade Organization; and subsequently the gradual move beyond that to free trade by Indonesia and other members of the Asia Pacific Economic Cooperation (APEC) grouping by 2020.

1.2 Environmental concerns in Indonesia

Indonesia is a particularly interesting case study of a large, rapidly developing economy with many current and potential environmental and natural resource concerns. Indonesia has vast natural resources that have helped to sustain

impressive economic growth since the mid-1960s (World Bank 1990). For two and a half decades prior to the current political and economic crisis, economic performance in Indonesia was one of the best in the world (Anderson and Pangestu 1995). With a population of just over 200 million (FAO 1997), Indonesia is already a very significant economy, and one that will continue to grow in global importance in future decades assuming that it recovers promptly from its 1997-98 financial crisis. Indonesia has a wealth of energy resources, including petroleum and coal, and potential for increased hydro and geothermal energy generation. It has fertile soils in Java and Bali and good soils in parts of Sumatra, Sulawesi and other islands. Closed-canopy forest covers more than half the country's land area, and Indonesia has the greatest degree of species biodiversity in Asia (World Bank 1990).

Although having only recently graduated out of the World Bank's low-income category,² Indonesia has shown a long-standing commitment to the basic concepts of sound environmental management and has already taken many concrete actions to improve environmental outcomes. For instance, an Agency for Environmental Impact Management (Bapedal) was set up in June 1990 and recent legislation requires environmental impact assessment for all major development projects (MacAndrews 1994). The national program of land rehabilitation and soil conservation was instigated by the Indonesian government in the mid-1970s to increase productivity of the critical upland regions and reduce soil erosion and a series of pilot projects during the 1980s

² 1996 per capita GNP was US\$1080 (World Bank 1998).

provided subsidies and technical assistance to farmers (Huszar et al. 1994). Further actions have included the nation-wide introduction of integrated pest management, strengthened forestry management and measures to assist pollution abatement (World Bank 1990).

Indonesia began formal regulation of water pollution in 1992 with the establishment of maximum allowable volumes and concentrations for emissions of biological oxygen demand (BOD) and other water pollutants from 14 broadly defined industry sectors (Pargal et al. 1997). Formal regulation of air and toxic pollution has also just been introduced (Pargal et al. 1997). Even though formal regulation of water and air pollution is only in its early stages, there appears to be evidence of a strong informal regulatory system in Indonesia. Pargal and Wheeler (1996) conducted econometric analysis on the determinants of pollution intensity at the plant level in Indonesia. Their results suggest that even in the absence of formal regulation, factory-level water pollution intensity in Indonesia seems very responsive to many variables which can be affected by non-environmental policies, such as the age of machinery, and the wealth and education of the community.

New facilities are cleaner than average existing plants and, for several major determinants of pollution intensity, recent trends in Indonesia appear very optimistic. If this cross-section evidence can be extrapolated to time series, there should be a large drop in the average pollution intensity of Indonesian manufacturing, regardless of the formal regulatory sector (Pargal and Wheeler

1996).³ A number of reasons are put forward for this, including the view that publicly-owned plants tend to be more pollution-intensive and there are not likely to be any new state enterprises in the industrial sector (Pargal and Wheeler 1996). In addition, with education and per capita income improving throughout Indonesia, the demand for higher environmental standards will continue to rise.

1.3 Interactions between output growth and the environment

There are competing views on the impact of market liberalization and economic growth on the natural environment. Property rights can provide the long-term incentives necessary to use resources sustainably. However, long lags may occur in developing legal and other infrastructure necessary to define and enforce property rights. Cumulative and possibly irreversible damage can occur during these lag periods (Ruttan 1991). Such problems beg the question of whether or not economic growth is environmentally sustainable.

Baldwin (1994) describes the accelerating harm to the environment as income rises, with the harm tapering and reversing at higher income levels, as an 'ecological transition'. When the level of economic activity is low, there is little pressure on the natural environment and damage is relatively low. As the level of economic activity rises, the demand for raw materials increases, as does

³ This finding is consistent with Duchin et al. (1993), who project large improvements in pollution-reducing production technologies, even in the absence of more stringent environmental policies.

pressure on the environment to absorb waste. Incentives may eventually emerge to conserve marketable natural resources, via rises in their price, and this conservation is reinforced by a more environmentally favourable composition of output as service industries expand their share of national income. Furthermore, once incomes grow beyond a certain threshold, the demand for environmental regulations also increases. There is therefore a possible inverse U-shaped relationship between per capita environmental damage and economic growth, with the turning point occurring at different income levels for different types of environmental damage (Grossman 1994, Lucas 1996, Radetzki 1992).

When output grows, the level of environmental damage is affected by at least three forces: changes in the level of aggregate economic activity, changes in the contribution of each sector to output, and changes in production technology (Dean 1996). The aggregate activity effect increases emissions due to increased total demand for goods from production and consumption. The intersectoral composition effect arises because some sectors are more polluting than others. Since some sectors may shrink while others expand in relative importance, changes in the composition of output will change pollution even if aggregate output remains constant. The third effect is caused by changes in production technology which influence the amount of degradation caused by each unit of output in each sector. This might be, for example, because income growth leads to increased effluent charges which encourage firms to shift to cleaner production processes (or simply because technology improves over time).

Chapter Two models the dynamic interaction between economic growth and environmental services. By allowing the growth rate of each variable to be affected by the presence of the other, the system can represent different views of the growth-environment debate, depending on the relationship assumed between the variables. This in turn depends in part upon the stage of development of the country in question. The first model presented in Chapter Two takes the pessimistic approach that the increased scale of output degrades the environment. We then model the optimistic view, where the positive environmental effects of changing intersectoral composition and improved production technology dominate. The impact of these effects can counter the aggregate activity effect and lead to a lower level of environmental degradation when output increases. To extend the pessimistic and optimistic views we add the positive impact of environmental services (or conversely the negative impact of environmental degradation) on output growth. This is potentially very important, particularly when production systems are largely natural resource-based and environmental services enter production functions directly. The models presented in Chapter Two enable us to derive policy-driven outcomes under various assumptions which can provide broad policy guidance for a growing economy.

1.4 Quantification of environmental effects

When optimal environmental policies are in place, economic reforms such as trade liberalization, like economic growth, will always improve national

economic welfare (Anderson and Blackhurst 1992). However, since optimal environmental policies are frequently not in place, particularly in poor countries, ambiguous environmental outcomes are possible as a consequence of market reforms and economic growth. In order to improve both environmental and economic outcomes, our understanding of the interactions between policy reform and the environment needs to improve. Quantification of the economy-environment linkages is necessary because the direction of some effects cannot be determined by a priori theoretical reasoning, and because some understanding of the relative importance of the various impacts is needed for priority setting by both researchers and policy makers (Anderson and Strutt 1996).

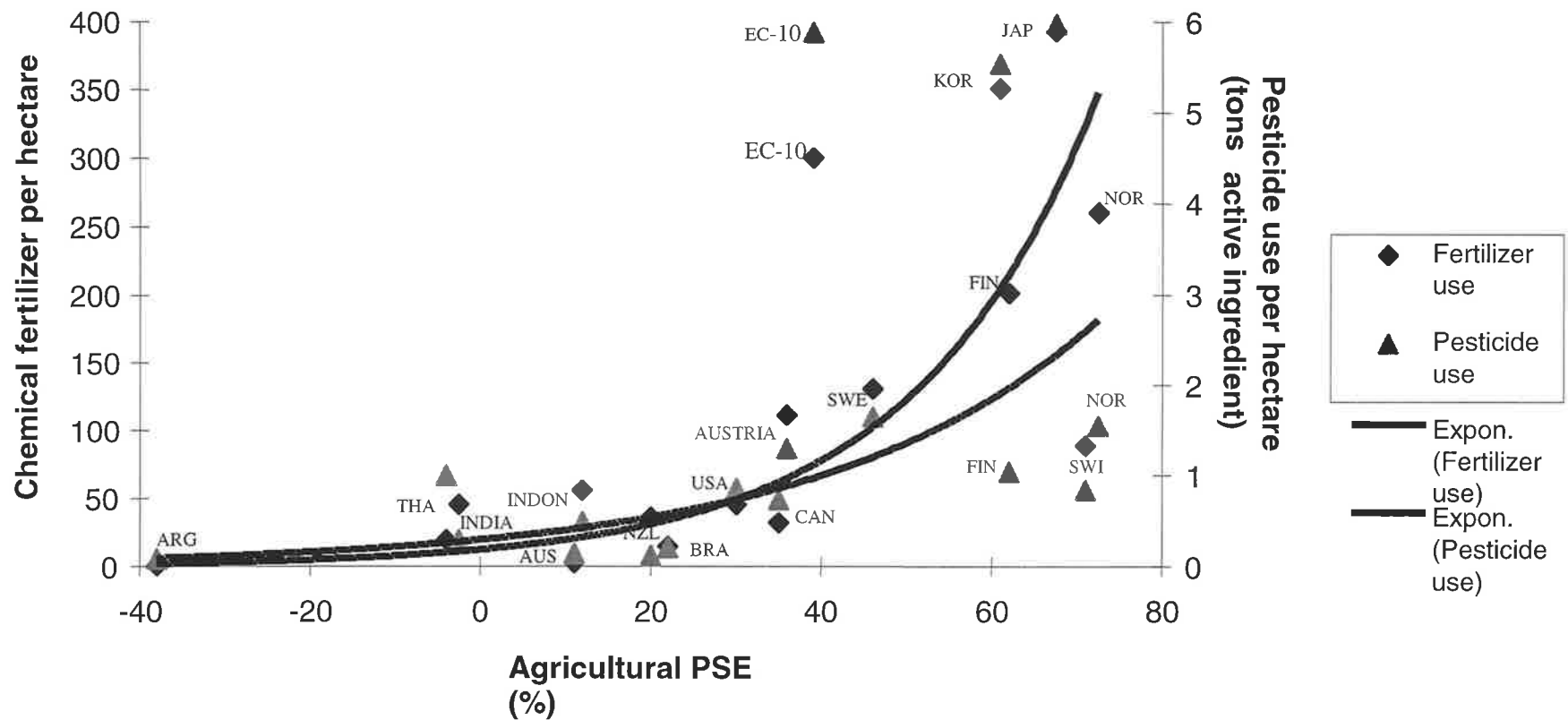
Quantifying environmental effects is challenging for a number of reasons. First, the natural environment has intertwined dimensions of quantity and quality, and there is often missing or ambiguous technical information. Second, the current condition and potential assimilative capacity of the natural environment varies by location, and for each region there will be a heterogeneous structure of opportunity costs. Valuation of damage will also vary by income level and region. Third, price signals induce substitution away from resources as they become relatively scarce, with the magnitude of the substitution parameters underlying utility and production functions typically not well known. Fourth, environmental effects are often cumulative and may involve relatively long time horizons.

Analysing the environmental effects of economic policy reform entails conceptualising complex and often poorly understood interactions between

economic and ecological variables. For example, the environmental links of agricultural production are two-way, with agricultural production affecting environmental quality and environmental quality affecting agricultural production. Appendix A summarises the major environmental impacts both arising from and affecting agricultural production. As shown, there are many interrelated variables and feedback effects, and measurement of even the major environmental effects is a non-trivial task. Some argue that the environmental consequences of human actions are far too complex to generalise (Just and Antle 1990). Certainly micro-approaches are important, but in our view, they should be supplemented and, to some extent, directed by more broad-based analysis that includes macroeconomic and intersectoral effects. Modelling environmental effects at the more aggregate level will of course involve making careful trade-offs.

Important insights can be gained with the use of existing economic policy models for examining the impact of reforms such as trade liberalization. For example, Anderson and Strutt (1996) examine the international relocation of agricultural production following Uruguay Round implementation, using results from a model of world food markets. There are important implications for environmental degradation and chemical residues in food, especially because the regions with contracting food output tend to be relatively densely populated and so use farm chemicals and intensive livestock methods much more than the expanding regions where food output expands. In the case of fertilizer and pesticides, for example, Figure 1.1 shows that the countries with high levels of farm price support use more than ten times as much farm chemicals per

Figure 1.1 *Relationship between agricultural producer subsidy equivalent (PSE) for 1979-89 and the use of chemical fertilizers per hectare and pesticides per 000 hectare of arable and pasture land*



Source: Anderson and Strutt (1996) based on World Resources Institute (1990, Table 18.2).

agricultural hectare as Australasia and most developing countries. Furthermore, land-scarce Western Europe and Japan on average crop twice as much of their total land area as does the rest of the world. This implies that the extent of contamination of their soil, water and air from the use of farm chemicals is even greater than Figure 1.1 suggests, relative to other countries. The relocation of food production from those densely populated protectionist countries to the rest of the world would cause a much larger reduction in degradation in the former compared with any increased degradation in the latter⁴ (Anderson and Strutt 1996).

These results from a model of world food markets tell only part of the environmental story, however. This is because reforms such as the Uruguay Round involve all policies, not just farm policies, and all sectors of the economy. For more comprehensive analysis, a global computable general equilibrium model is preferred. Such a model can capture the impacts of finite resources shifting between sectors, and policy options and decisions can be analysed by examining their impact on all sectors and regions of the world.

1.5 Computable general equilibrium modelling of environmental effects

Computable general equilibrium modelling provides a powerful tool for simulating and analysing structural and policy changes which have economy-

⁴ Where chemical use would expand from a low base and to still-modest levels.

wide impacts. Many policy reforms such as trade liberalization -- even if directed to just one sector -- affect other sectors of the economy, and this can only be captured in a multisectoral economy-wide model. This movement of activity between sectors is important when considering environmental effects, since an environmental improvement in one sector may be at the expense of damage in other sectors. Furthermore, most reforms are piecemeal with the impacts depending in part on remaining distortionary policies, again requiring a system-wide analysis.

Increasing levels of experience and improved computational capability have led to significant advances in computable general equilibrium (CGE) modelling in recent years. Extending these models to incorporate explicitly non-marketed environmental impacts will further increase their capacity to project the outcomes of various policy changes. If values can be attached to the various types of environmental damage, a fuller welfare analysis is possible (Anderson and Strutt 1996).

Computable general equilibrium models have tight theoretical specifications and, unlike econometric models, they are able to provide insights into changes when we have an understanding of the mechanisms but there is no historical experience in the data (Dixon and Parmenter 1994). This makes them particularly attractive for modelling prospective structural and policy changes and their environmental effects. Environmental damage is frequently cumulative and sometimes irreversible, and where such environmental thresholds exist, they can be modelled as exogenous shocks to the system. A recent United States

Department of Agriculture (USDA) report applies this kind of approach by exploiting forecasts of global warming in a geographic information system to calculate the anticipated impact on land and water resources. The changed endowments are then fed in as potential shocks to the natural resource endowments in a global trade model (Darwin et al. 1995).

CGE models have a powerful capacity to incorporate new theoretical and empirical evidence as it appears, in a useable and relatively transparent manner. There has been an avalanche of research on environmental issues in recent years, and explicit modelling facilitates discussion of the way in which the results of this environmental research can be used appropriately. Enormous potential exists for specialization by researching according to one's own comparative advantage, and drawing on the work of other experts both within and outside the economics discipline. A further advantage of such an approach is the probability of motivating more empirical work on the parameters and linkages where the models are at their weakest. Indeed CGE models can be used to help show which parameters are most critical, thereby narrowing the range of essential econometric and other research needed (Anderson and Strutt 1996).

Existing national or global general equilibrium models used for trade liberalization simulations can be expanded to include environmental damage functions. Incorporating the major land classes may significantly increase the power of the model to analyse environmental impacts. Tobey and Reinert (1991) provide an example of a simple national model with only one agricultural industry and one environmental damage function. Using this stylised model,

Tobey and Reinert (1991) distinguish between highly- and non-erodible land. Coxhead and Jayasuriya (1994) present a stylised CGE model for a developing Asian country that has two agricultural regions (upland and lowland) and one other (tradable manufacturing). It simply infers land degradation changes from the switching in the use of upland between food and tree crop production. Somaratne et al. (1997) present preliminary results for Sri Lanka which show that trade liberalisation in non-plantation agriculture is an environmentally friendly policy which leads to both higher economic growth and reduced environmental degradation. Darwin et al. (1995) use a global CGE model and categorise six different land classes, according to the length of growing season. They use a constant elasticity of transformation (CET)⁵ function, with an Allen partial elasticity less than zero to restrict the mobility of land between sectors and reflect the inherent productivity differences of land (Darwin 1995). As the elasticity of transformation becomes larger in absolute value, the degree of sluggishness decreases and land becomes a relatively mobile factor with similar rents across sectors. Gray et al. (1995) examine a policy of setting aside more land for conservation areas; either the endowment levels for land can be exogenously shocked, or taxes can be imposed on other types of land to induce a reduction in usage.

A number of efforts have been made by researchers to examine environmental damage across all sectors of an economy. Beghin et al. (1994) provide an algebraic prototype national CGE to be used in a project at the OECD

⁵ The CET revenue function is analogous to the CES cost function (see Hertel and Tsigas 1997).

Development Centre. That work focuses on the emission of industrial pollution and specifies emissions (from manufacturing only) simply as proportional to output. A commonly used approach for modelling industrial pollution is to use pollution intensity data for the United States, from the Industrial Pollution Projection System (IPPS) developed by World Bank staff, which allows estimates of industrial pollution to be made from manufacturing activity data (Hettige et al. 1994). This output emission intensity can be imposed on other regions (Beghin et al. 1994, Lee and Roland-Holst 1997), however, there are clear limitations to this approach, especially when quite different production technologies and levels of damage and abatement are evident across countries. In addition, the commodities produced, the resource endowments used, and geographic characteristics vary enormously, and these may be particularly important when examining developing countries.

Dessus et al. (1994) make a very useful attempt to sharpen industrial pollution analysis by looking at the nature of inputs to production, rather than outputs. This work recognises that industrial processes may vary by country and that transferring effluent coefficients for industrial output from the US to other countries effectively ignores differences in technology, resource intensity and input composition. The authors find that over 90 per cent of the variation in output of most toxic pollution can be explained by the consumption of less than a dozen intermediate inputs. Measuring effluent contributions by quantifying the use of these inputs may therefore provide a very good indication of damage. Beghin et al. (1996) have developed a prototype CGE model which uses this approach to link emissions to consumption of polluting inputs rather than

output. They have applied these input based measures of pollutants in a number of country studies including Mexico and Chile (Beghin et al. 1997 and 1998).

1.6 Extending a CGE model to include environmental effects

Most economic models, including CGE models, abstract from non-marketed transactions such as environmental damage. Some extensions are required before standard CGE models are able to explicitly examine environmental effects. This section outlines the non-marketed effects not generally modelled and suggests mechanisms by which environmental impacts might be incorporated directly into a model.

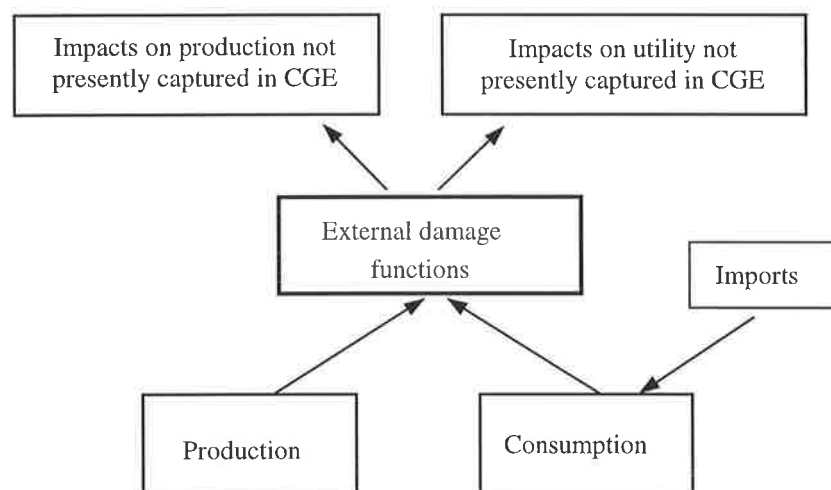
There are two major areas in which CGE models can be extended to better capture environmental effects. The first is that of adverse feedback effects on production. For example, farmers may act in the absence of full information and demand ‘too much’ production from their land: initial land degradation may go unnoticed by the farmer, who does not realise that the long-term productive capacity of the land is being harmed.⁶ The second major area of concern is non-marketed environmental externalities which may arise due to the absence of adequate property rights (or their enforcement) or because of insufficient information. Property rights may be inadequate to protect neighbouring property, national and global environmental resources, or future generations. But

⁶ Incomplete information may of course be rational and optimal in some cases, though this is likely to diminish as the value of land rises and farmers find it increasingly in their interest to demand more information on preserving the quality of their land.

even where property rights are fully defined, there may be difficulties in assessing the cause of damage and the compensation required. For example, limited scientific information on the cause and impact of non-point pollution may render it difficult to reach Coasian solutions.

Figure 1.2 suggests the major mechanisms by which current model specifications are unlikely to capture environmental impacts. The negative effects of external damage functions on utility, and their feedback effects on production, are important additional relationships to include in the model.⁷

Figure 1.2 *Environmental extensions to a CGE model*



For resources that do not have stock feedback effects, environmental degradation can be modelled either as a factor of production (López 1994), or as a joint product in the output of production (Copeland 1994, Tobey and Reinert

1991). When stock feedback effects exist, production can expand in the short run by more intensive exploitation, but at the cost of a reduction in the stock and therefore in future production (López 1994).⁸ Production will be inversely related to the level of degradation.

Environmental degradation accumulates into environmental damage that can adversely affect utility levels. Utility can be derived from a composite of marketed commodities and non-marketed environmental services. Environmental services are often not actually purchased, and they have no explicit income elasticity.⁹ Since explicit markets do not exist for environmental damage caused by externalities, the impact on utility must be valued and subtracted from the equivalent variation determined by marketed commodities. There have been some advances, but little consensus, in valuing non-marketed environmental services (Smith 1990 provides a survey). Some authors have exploited the concept that the marginal valuation of environmental damage is likely to be substantially higher in rich countries than poor countries (eg. Perroni and Wigle 1997), though estimates are somewhat arbitrary. It may therefore sometimes be more appropriate to express environmental damage in physical terms when examining trade-offs.

⁷ Coxhead (1996a) uses the example of agricultural growth, which may cause soil depletion or off-site externalities, to suggest that a less than full valuation of the resource costs of growth will cause standard factor prices to be misleading signals of factor scarcity.

⁸ Soil degradation, for example, is likely to be an important feedback effect in agricultural production.

⁹ Though environmental taxes could of course be endogenised to increase with income.

Ideally, feedback effects on production along with environmental damage equations will be incorporated directly into a CGE model. The use of environmentally damaging inputs will be captured in damage equations that inversely affect utility and form a negative feedback loop into the production function. However, given the paucity of current environmental data, a blunter approach may be appropriate initially. A more simple approach has the advantage of substantially reducing the work required to adapt the database and structure of an existing model, thus enabling increased concentration on what may be the more pressing tasks of formulating environmental damage functions and prioritising areas of environmental and economic concern. The innovative work of Perroni and Wigle (1997) demonstrates the potential for using an environmental side-model to make use of available data, and running this in tandem with a CGE model of the world economy.

In Chapters Three, Four and Five we use modified versions of the Global Trade Analysis Project (GTAP) model to examine first land degradation, including feedback effects on production, and then air and water pollution in Indonesia from 1992-2020. The GTAP model is a comparative-static multi-region computable general equilibrium model of the Johansen type that is based on the SALTER model (Jomini et al. 1991). Version 3 of GTAP has 37 sectors and 24 countries or regions, of which Indonesia is one (Hertel 1997). It is a publicly available, fully documented model with an excellent, well-maintained and

regularly updated data base.¹⁰ The model is implemented and solved using GEMPACK (Harrison and Pearson 1996).

1.7 Structure of the thesis

Trade policy reform, economic growth and structural change will affect environmental damage in Indonesia. Measuring environmental impacts is not an exact science, with complex modelling hindered by scarce environmental data and uncertainty. However, simply using a priori theoretical reasoning or ignoring the more difficult and contentious issues will not improve economic or environmental outcomes. The most efficient way to improve our understanding and ensure the best outcome, given incomplete information, is to model what we are able, recognise its limitations, and open the issue to debate. The additional advantage of this approach is that it helps to identify crucial areas of concern in order to direct future research and encourage better estimation of key parameters.

We develop a theoretical model of the interactions between growth and the environment in Chapter Two, including linking this model to the scale, technique and composition environmental effects of economic growth. This model shows the potential importance of including environmental damage and feedback effects in our analysis. However its policy conclusions are too broad to be applied in many practical situations. For quantification of the possibly

¹⁰ See Hertel (1997) and McDougall (1997) for detailed descriptions of the GTAP model and data

ambiguous environmental effects which arise from policy reform, we use environmental side modules along with a modified global trade model. When environmental modules are added to a model of Indonesia's economy, it is possible to estimate the impact of economic growth and policy reform on natural resources and the environment.

Chapter Three examines land degradation in Indonesia and includes negative feedback effects in a global CGE model. To keep the task manageable, attention is focused on land degradation in the agricultural sector, where the environmental feedback effects on production may be particularly important. Agriculture is a significant sector in many developing countries such as Indonesia. While its relative size tends to decline as the country industrialises, agriculture still remains large in absolute terms and there may be increasing pressures for agricultural assistance.

Although the initial focus of this study is the agricultural sector in Indonesia, environmental damage in other sectors cannot be ignored if net national environmental outcomes are considered important. In Chapters Four and Five we model air and water pollution across all sectors in Indonesia from 1992-2020 since environmental data for air and water pollution is available for the period to 2020 (Duchin et al. 1993). This work differs from Chapter Three where land

degradation data enabled an approximation of feedback effects,¹¹ but only for the benchmark year.

Chapter Four develops the GTAP model used in Chapter Three to project the world economy to 2020. We introduce specific factors of production in the natural resource sectors, split the single factor labour into skilled and unskilled labour, and increase the Armington trade elasticities. These modifications better equip the model to deal with the large structural changes that are simulated when projecting over such a long time period. In addition to modelling the structural change over this time period, we model implementation of the agreed Uruguay Round and APEC trade liberalizations. Chapter Five adds environmental side modules for air and water pollution to the Indonesian part of that GTAP model, and then examines the effects of this structural change and trade reform on the level of environmental damage in Indonesia. We include a decomposition to show separately the contributions of the aggregate activity, technology and intersectoral composition environmental effects due to economic growth and trade policy reform. The concluding chapter draws together the key findings and points to directions for further research.

¹¹ Feedback effects are likely to be particularly significant in the case of land degradation. However in the case of air and possibly water pollution, the direct effects on production may be much less significant (see for example López 1994).

2. INTERACTIONS BETWEEN OUTPUT GROWTH AND THE ENVIRONMENT¹

2.1 Introduction

Environmental pessimists contend that increases in economic output degrade the environment. This results in policy dilemmas, whereby output-stimulating policies such as trade liberalization must be traded off against environmental concerns. In this chapter we question this view. Even if increased output directly causes environmental degradation, environmental services can enhance output growth. This gives rise to models that suggest the reverse of the pessimistic outcome may emerge.

This chapter seeks to contribute to the theoretical literature on growth-environment interactions by modelling the interactions between output and the environment in a simple dynamic model. Dynamic models have appeared in much of the environmental economics literature (eg, Dasgupta and Heal 1974, Tahvonen and Kuuluvainen 1993 and Beltratti 1995). Our models explicitly incorporate environmental dynamics, especially the contribution of environmental services to output growth. López (1994) shows that when feedback effects exist, an expansion in production in the short run may be at the cost of a reduction in the stock of natural resources, and therefore future production. Our simple dynamic model shows the potential importance of

¹ This chapter draws on joint work with Steven Lim and Derek Harland (Strutt, Lim and Harland 1997).

including environmental damage and feedback effects on production. It enables us to present a taxonomy of growth-environment interactions, and show that policy changes may have unexpected results.

When output grows, the level of environmental damage is affected by at least three forces: changes in the level of aggregate economic activity, changes in the contribution of each sector to output, and changes in production technology (see Chapter 5, Copeland and Taylor 1994 and Dean 1996). The aggregate activity effect increases emissions due to the increased level of economic activity. The intersectoral composition effect arises because some sectors are more polluting than others and some sectors may shrink while others expand in relative terms. The third effect is caused by changes in production technology which influence the amount of degradation caused by each unit of output in each sector. This might be, for example, because income growth leads to increased effluent charges which encourage firms to shift to cleaner production processes (Dean 1996).

The first model we present takes the pessimistic approach that the increased scale of output degrades the environment. We then model the optimistic view, where the positive effects of changing intersectoral composition and improved production technology dominate. The impact of these effects can counter the aggregate activity effect and lead to a lower level of environmental degradation when output increases.

To extend the pessimistic and optimistic views we add the positive impact of environmental services on output growth. This is potentially very important, particularly when production systems are largely natural resource-based and environmental services enter production functions directly. With an increased stock of natural resources a country can produce more, *ceteris paribus* (Huang and Rozelle 1995, World Bank 1992). Countries producing environmental goods and services may also be well poised to take advantage of the high income elasticity of demand for such commodities. Eco-tourism is one example; other opportunities may be due to technological advantages in environmentally-friendly production. The positive influence of environmental services on output growth may also be indirect. Some environmental externalities are large enough to alter input productivity (Antle and Pingali 1994). For example, an improvement in environmental quality from reduced soil erosion or increased availability of clean air and water is likely to lead to higher factor productivity.

Adding these environmental dynamics to the view that output growth harms the environment introduces feedback effects. Feedback within the pessimistic model widens the interrelationships between output and the environment. A number of interesting results emerge from this, leading to a reassessment of the policy trade-offs between the environment and growth. For example, a “green” technology designed to enhance the environment, but ostensibly harming output growth rates, can *raise* output levels. On the other hand, a dirty technology designed to increase output growth rates can reduce the equilibrium levels of *both* output and environmental services.

We also present the conditions under which total environmental degradation might occur. These conditions help to identify environmentally “at risk” countries or scenarios and suggest remedial policy actions. We show that standard productivity-enhancing policies, which take no account of their environmental impacts, might be inappropriate for such economies.

The optimistic model relates to the empirically observed inverted-U relationship between per capita income and certain types of environmental degradation (eg, see Grossman and Krueger 1995). Here output growth and environmental services exist in mutual support once a critical per capita income threshold has been reached. In this model a policy which stimulates output growth alone, or that of environmental services alone, *must* increase the equilibrium values of both. But a dirty technology, which ostensibly increases output at the expense of the environment, can increase or decrease the equilibrium values of both. In this scenario, a dirty technology no longer has to harm the environment, and “green” policies can now lead to a fall in both output and environmental services. We also discuss the potential fragility of the environment, even where output growth helps the environment.

2.2 The basic model

Let Y represent the level of output, net of investment in environmental services, and E the level of environmental services. Output growth refers to increases in

physical output (such as that of a single good or an aggregate like national income). Environmental services relate to the benefits provided by the natural environment, which we define broadly to include both stock and flow effects. For example, either the depletion of natural resources or the emission of pollutants by production may depreciate the services provided by the natural environment.

The growth of Y and E are modelled by the differential system:

$$\frac{dY}{dt} = F(Y, E, \underline{\tau})Y \tag{1}$$

$$\frac{dE}{dt} = G(Y, E, \underline{\tau})E ,$$

where $\underline{\tau} = (\tau_1, \tau_2, \dots, \tau_n) \in \mathfrak{R}^n$ is a vector of parameters representing the state of technology existing in the economy. The growth rates F and G are C^1 functions of the non-negative variables E and Y .

Given the level of technology, $\underline{\tau}$, a long run equilibrium or steady state of the system may only exist where $\frac{dY}{dt} = \frac{dE}{dt} = 0$. Points (E^*, Y^*) , with $F(Y^*, E^*, \underline{\tau}) = 0$ are points satisfying output equilibrium, since here output has no tendency to change. Similarly, if $G(Y^*, E^*, \underline{\tau}) = 0$, then (E^*, Y^*) is an environmental equilibrium.

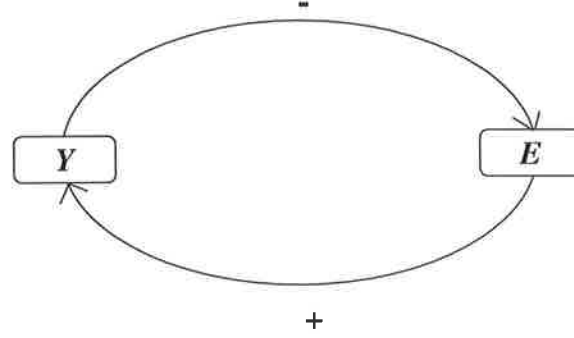
By allowing the growth rate of each variable to be affected by the presence of the other, the system (1) can demonstrate a pessimistic or optimistic view on the growth-environment debate, depending on the relationship assumed between the variables.

2.3 The pessimistic view: output growth degrading the environment

2.3.1 Modelling the pessimistic view

The purported negative link between growth and environmental degradation is of primary concern to some people. This concern is heightened in the case of developing countries, since some of the most populous nations are growing at, or are poised to grow at, very high rates by historical standards. Much of the concern with the environmental consequences of output growth is motivated by a belief that high output growth rates place heavy demands on the stock and assimilative capacity of natural resources. The negative relationship is summarised by the top arrow in Figure 2.1. The implication of this pessimistic view is that long run environmental sustainability requires curtailing output growth. We modify this approach by introducing positive feedback links, where an improved stock of environmental resources can lead to higher output levels, as indicated by the bottom arrow in Figure 2.1.

Figure 2.1 *Interactions between Y and E: pessimistic view*



To model the pessimistic view and feedback links, we make the following set of assumptions (A1):

- (i) $F_Y < 0, F_E > 0, G_Y < 0, G_E < 0$. That is, Y inhibits its own growth and also that of the environment. E inhibits its own growth but spurs the growth of output (ie, all else being equal, countries or production systems with a higher natural resource base and lower pollution levels have faster output growth).

We assume initially that $F_{\tau_i} \geq 0 \forall i$. This implies that technological change maintains or increases the ability of output to grow, for example through more efficient use of resources. For now we make no assumptions about the impact of technological change on the growth of the environment: G_{τ_i} can be greater than, less than or equal to zero.

Assumptions (ii) - (v) are made for each level of technology $\underline{\tau}$:

(ii) $F(0,0,\underline{\tau}) > 0$ and $G(0,0,\underline{\tau}) > 0$. That is, each variable will increase if both are small.

(iii) There exists $Y_\tau > 0$ such that $G(Y_\tau,0,\underline{\tau}) = 0$. That is, an equilibrium level of production exists that will exhaust the environmental resources in an environmental equilibrium. Even if small, environmental services cannot grow in the presence of too large a level of output, since output is a competing variable.

(iv) There exists $y_\tau > 0, E_\tau > 0$ such that $F(y_\tau,0,\underline{\tau}) = G(0,E_\tau,\underline{\tau}) = 0$. For example, $F(y_\tau,0,\underline{\tau}) = 0$ means that in the absence of a change in the level of environmental services or technology, the economy cannot grow beyond size y_τ . This could be the result of factors such as resource constraints or the size of domestic and international markets.

(v) For each E there exists $\bar{Y}$ such that $F(\bar{Y},E,\underline{\tau}) < 0$. This assumption effectively ensures the existence of a bound to output in output equilibrium.

Lemma 1 With assumptions (i)-(v), the equations $F(Y, E, \underline{\tau}) = 0$ and $G(Y, E, \underline{\tau}) = 0$ implicitly define continuous functions $Y = f(E, \underline{\tau})$ and $E = g(Y, \underline{\tau})$, respectively. These are both defined on the interval $[0, E_\tau]$ for each τ and satisfy:

- (a) $f_E > 0, g_E < 0$
- (b) $g(E_\tau, \underline{\tau}) = 0$
- (c) $f(0, \underline{\tau}) = y_\tau, g(0, \underline{\tau}) = Y_\tau$
- (d) f and g are one-to-one.

Proof Let τ be a technology and suppose that $E \in [0, E_\tau]$. As $F(0, 0, \underline{\tau}) > 0$ and $F_E > 0$, then $F(0, E, \underline{\tau}) > 0$. By assumption (v) there exists $\bar{Y}$ with $F(\bar{Y}, E, \underline{\tau}) < 0$ and by the intermediate value theorem there is a value Y_1 such that $F(Y_1, E, \underline{\tau}) = 0$. As $F_Y < 0$ for all Y this is unique, and thus $f(E, \underline{\tau}) = Y_1$ defines our function f . Similarly, we may define g . Both f and g are differentiable with respect to E on their domains as $f_E = -F_E / F_Y$ and $g_E = -G_E / G_Y$. Properties (a), (b), (c) and (d) follow from our assumptions.

Lemma 2 Assume (i)-(v) hold and let $\underline{\tau}$ be a technology satisfying $Y_\tau > y_\tau$. Then a stable long run solution Y^*, E^* to the system (1) exists, with $Y^* > 0$, $E^* > 0$.

Proof By Lemma 1, $F=0$ and $G=0$ implicitly define $Y=f(E,\underline{\tau})$ and $Y=g(E,\underline{\tau})$ respectively, where both f and g are defined on $[0,E_\tau]$, with $g(E_\tau,\underline{\tau})=0$ and $f(0,\underline{\tau})=y_\tau$. Consider $f-g$: by Lemma 1, $f_E > 0$ and thus $f(E_\tau,\underline{\tau}) > f(0,\underline{\tau}) > 0$. Hence:

$$f(E_\tau,\underline{\tau}) - g(E_\tau,\underline{\tau}) = f(E_\tau,\underline{\tau}) > 0$$

$$f(0,\underline{\tau}) - g(0,\underline{\tau}) = y_\tau - Y_\tau < 0.$$

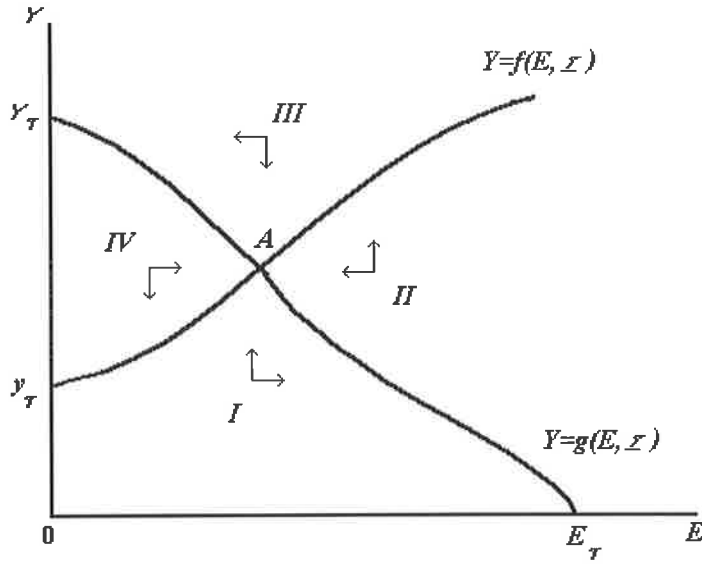
Thus there exists Y_τ^*, E_τ^* such that $F(Y_\tau^*, E_\tau^*, \underline{\tau}) = G(Y_\tau^*, E_\tau^*, \underline{\tau}) = 0$. So for fixed $\underline{\tau}$, (E_τ^*, Y_τ^*) is a steady state of (1). To determine stability, we compute the eigenvalues λ of:

$$\det \left\{ \begin{bmatrix} \frac{\partial}{\partial Y} F(Y, E, \underline{\tau}) Y & \frac{\partial}{\partial E} F(Y, E, \underline{\tau}) Y \\ \frac{\partial}{\partial Y} G(Y, E, \underline{\tau}) E & \frac{\partial}{\partial E} G(Y, E, \underline{\tau}) E \end{bmatrix}_{Y=Y_\tau^*, E=E_\tau^*} - \lambda I \right\} = \det \begin{bmatrix} F_Y Y - \lambda & F_E Y \\ G_Y E & G_E E - \lambda \end{bmatrix}$$

This has two distinct eigenvalues λ_1, λ_2 with $\text{Re}(\lambda_i) < 0, i=1,2$. Thus, (E_τ^*, Y_τ^*) is a stable steady state.

Figure 2.2 shows the phase diagram for this scenario. The curves $Y=f(E,\underline{\tau})$ and $Y=g(E,\underline{\tau})$ represent isoclines, since along these curves $F=0$ (output equilibrium) and $G=0$ (environmental equilibrium), respectively.

Figure 2.2 Phase diagram



The axes, f and g generate four open sets, where $\dot{Y} \neq 0$ and $\dot{E} \neq 0$. These are:

$$I: \left\{ (E, Y): \dot{Y} > 0, \dot{E} > 0 \right\},$$

$$II: \left\{ (E, Y): \dot{Y} > 0, \dot{E} < 0 \right\},$$

$$III: \left\{ (E, Y): \dot{Y} < 0, \dot{E} < 0 \right\},$$

$$IV: \left\{ (E, Y): \dot{Y} < 0, \dot{E} > 0 \right\}.$$

Point $A = (E_\tau^*, Y_\tau^*)$ is the stable equilibrium point.

The previous lemma asserts the existence of a stable long run solution to the system for each technology τ with $Y_\tau > y_\tau$. Let $Y = h_1(\tau)$, $E = h_2(\tau)$ represent

these stable solutions, where h_1, h_2 are defined on $T = \{\underline{\tau}: Y_{\tau} > y_{\tau}\}$. We are interested in the effect of small changes in technology on the long run outcomes. That is, if the parameter τ_i changes, how are $Y = h_1(\underline{\tau})$ and $E = h_2(\underline{\tau})$ affected?

Lemma 3 Consider the system (1) with assumptions (i)-(v) and let $Y = f(E, \underline{\tau})$, $E = g(Y, \underline{\tau})$ be solutions to $F = 0$ and $G = 0$, respectively. Define h_1 and h_2 on T as above. For a technology parameter τ_i :

$$\frac{\partial E}{\partial \tau_i} > 0 \Leftrightarrow \frac{\partial g}{\partial \tau_i} > \frac{\partial f}{\partial \tau_i} \quad (2)$$

$$\frac{\partial Y}{\partial \tau_i} > 0 \Leftrightarrow \frac{\partial g^{-1}}{\partial \tau_i} > \frac{\partial f^{-1}}{\partial \tau_i} \quad (3)$$

where f^{-1}, g^{-1} are defined such that $f(f^{-1}(Y, \underline{\tau}), \underline{\tau}) = Y$, $g(g^{-1}(Y, \underline{\tau}), \underline{\tau}) = Y$.

Proof By the implicit function theorem, as $Y = h_1(\underline{\tau}), E = h_2(\underline{\tau})$ are solutions to $F = G = 0$, then:

$$\begin{bmatrix} \frac{\partial h_1}{\partial \tau_i} \\ \frac{\partial h_2}{\partial \tau_i} \end{bmatrix} = \begin{bmatrix} \frac{\partial Y}{\partial \tau_i} \\ \frac{\partial E}{\partial \tau_i} \end{bmatrix} = \frac{1}{F_Y G_E - G_Y F_E} \begin{bmatrix} F_E G_{\tau_i} - G_E F_{\tau_i} \\ F_{\tau_i} G_Y - F_Y G_{\tau_i} \end{bmatrix}.$$

By our assumptions on F and G , $F_Y G_E - G_Y F_E > 0$, therefore:

$$\frac{\partial E}{\partial \tau_i} > 0 \Leftrightarrow F_{\tau_i} G_Y - F_Y G_{\tau_i} > 0$$

$$\Leftrightarrow \frac{-F_{\tau_i}}{F_Y} < \frac{-G_{\tau_i}}{G_Y}$$

$$\Leftrightarrow \frac{\partial f}{\partial \tau_i} < \frac{\partial g}{\partial \tau_i}$$

by the implicit function theorem. The second result follows similarly.

2.3.2 Comparative dynamics: Implications of Lemma 3

Lemma 3 has several important implications, depending on the shifts and relative magnitudes of $\partial f / \partial \tau_i$ and $\partial g / \partial \tau_i$. We examine the implications of six possible cases separately:

Case 1 *Output-increasing technology (such as trade reform)*

Let a change in technology directly raise the growth rate of output (ie, $F_{\tau_i} > 0$), but have no direct impact on that of environmental services (ie, $G_{\tau_i} = 0$). That is, $\partial f / \partial \tau_i > 0, \partial g / \partial \tau_i = 0$. This is represented in Figure 2.3 by the upward shift of the f isocline from the initial f to f_I , with g unchanged. The overall equilibrium point, once feedback effects with the environment are included, moves from A to C . Thus, output projections which failed to take the environment into account (such as AB) would *overstate* the impact on output.

This is because the change in output harms the environment, which feeds back to impede the overall increase in output.

Case 2 *Environmental services-increasing technology*

Let a change in technology directly raise the growth rate of environmental services but have no direct impact on that of output; ie, $\frac{\partial f}{\partial \tau_i} = 0, \frac{\partial g}{\partial \tau_i} > 0$.

Then a policy which increases the level of environmental services raises output, as well as the equilibrium level of environmental services. This is illustrated in Figure 2.3 by the shift from the initial g to g_1 , with f stationary. The resulting equilibrium is point H . Thus projections that fail to take the growth in output into account (such as AD) would overstate the impact on the environment and understate the growth in output.

Case 3 *Output and environment services-increasing technology*

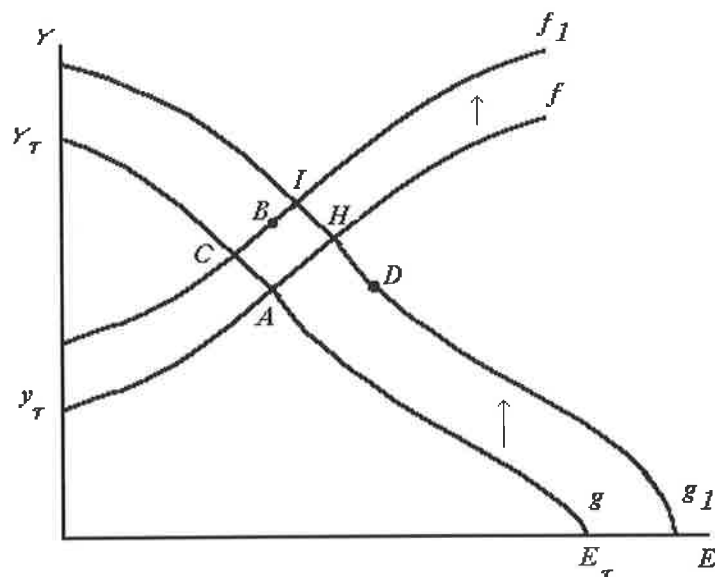
Assume that technology helps the growth of both E and Y ; ie, $F_{\tau_i} > 0, G_{\tau_i} > 0$.

In this case, $\frac{\partial g}{\partial \tau_i} > 0$ and $\frac{\partial f}{\partial \tau_i} > 0$. However, Lemma 3 implies that even though this technology parameter helps the growth of environmental services, a small change may create an equilibrium where the environment is worse off. For example, the introduction of property rights designed to stimulate output growth and help the environment may actually make the environment worse off, although from (3) output must rise.

From a policy perspective, for the environment to be better off, the change must increase the level of output consistent with environmental equilibrium at the initial level of E . And it must do this by more than it increases the level of output consistent with output equilibrium, again at the initial level of E . If $\partial g / \partial \tau > \partial f / \partial \tau$, then E must increase, ie, $\partial E / \partial \tau > 0$. From Figure 2.3, the illustrated change in technology moves the system from A to I , with an increase in output and environmental services.

There is anecdotal evidence of this kind of “win-win” policy. For example, some industries subject to the most stringent environmental regulations have become among the most efficient in the United States, and have even improved their international competitiveness (Bezdek 1993:9, Porter 1990). The implication is that when companies face incentives to tighten up on their exploitation of environmental services, a general increase in efficiency may be induced (Porter and van der Linde 1995). It should be noted, however, that this is a contentious issue, with other economists arguing that environmental policies will not be at zero cost. See, for example, the discussions in Palmer, Oates and Portney (1995) and Jaffe et al. (1995).

Figure 2.3 Graphical illustrations of Lemma 3: cases 1, 2 and 3



Case 4 “Dirty” technology

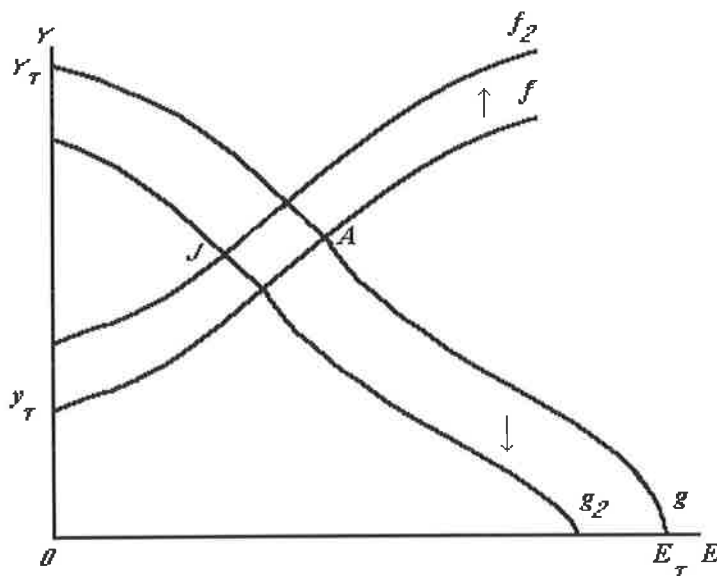
Let $\frac{\partial g}{\partial \tau_i} < 0$, $\frac{\partial f}{\partial \tau_i} > 0$. Here technology reduces the growth rate of E and increases that of Y (ie, a “dirty” technology). From the lemma, small increases in this technology will hurt the environment. The effect on output is indeterminate, and may be negative even though this technology was intended to help output growth.

As the economy moves between the equilibria, the application of dirty technology causes Y to rise and then fall, possibly to a lower level than it started at. The initial rise in income with the use of dirty technology is therefore no guarantee of a rise in long run output. The movement from A to J in Figure 2.4

illustrates the negative impact on the environment and a negative effect on income.

An example of policy-driven “dirty” technology was the large subsidization of pesticides in Indonesia. The aim of this policy was to increase productivity and shift f upward. One of the unintended impacts of the increased pesticide usage was to harm the natural environment by wiping out natural predators of the brown planthopper. The brown planthopper outbreak caused the loss of 50-60,000 hectares of irrigated rice in 1986-87 (Barbier 1989: 889). This effectively caused g to shift down.

Figure 2.4 *Application of “dirty” technology*



Case 5 “Green” technology

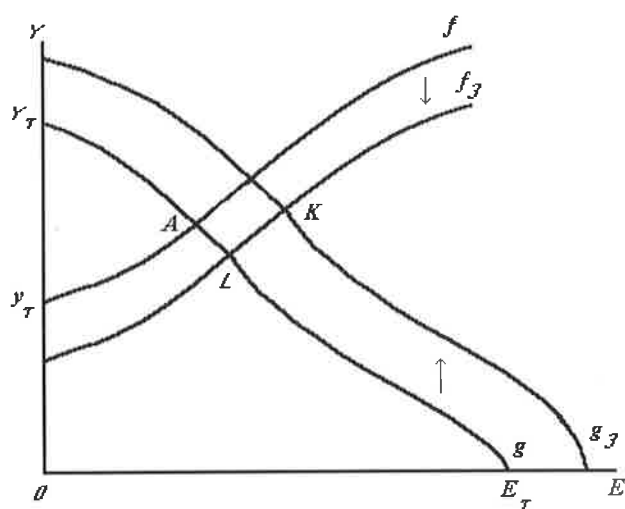
Now we relax the assumption that $F_{\tau_i} \geq 0 \forall i$. Let $\partial f / \partial \tau_i < 0$, $\partial g / \partial \tau_i > 0$. Such a technology ostensibly hurts the output growth rate, while enhancing that of environmental services (let’s call this a “green” policy). Surprisingly, such a policy can actually *increase* output as well as improve the level of environmental services. Figure 2.5 illustrates the point, as the economy moves from A to K .

Suppose initially that stringent environmental policies impose constraints on production, such that output falls. The fall in output reduces the pressure on the environment and E rises. This is shown in the diagram as the movement from A

to L . Let the policy also help the environment directly, such that $\partial g / \partial \tau_i > 0$.

Depending on the size of the shifts in the f and g isoclines, this policy could improve output and the environment. In other words, a shock which initially hurts output, countered with a policy that improves the environment, can raise the equilibrium levels of both. In general, the positive effect on the level of environmental services is clear; the effect on output is more ambiguous.

Figure 2.5 *Impact of a “green” policy on output*



Cases 1-5 are summarised in Table 2.1.

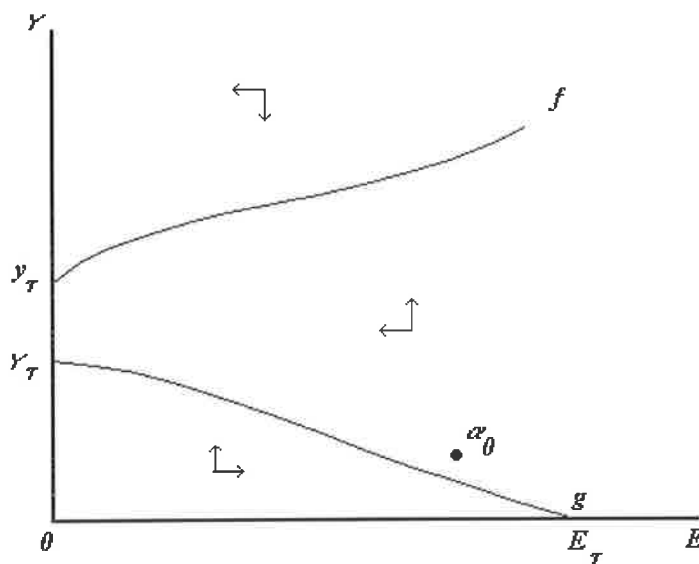
Table 2.1 *Summary of cases*

Case	Policy Objective/ Initial impact	Equilibrium	
		Y	E
1. Output technology (eg trade reform)	increase F	+	-
2. Environmental technology	increase G	+	+
3. “Win-win” technology	increase F increase G	+	?
4. “Dirty” technology	increase F decrease G	?	-
5. “Green” technology	decrease F increase G	?	+

2.3.3 Environmentally fragile systems: An extreme case

Now we relax the assumption that $Y_\tau > y_\tau$. Most of the assumptions in this model have been geared towards producing functions f and g that are positively or negatively sloped, defined in an appropriate interval and with an interior solution to $f=g$. Replacing the assumption that $Y_\tau > y_\tau$ with $y_\tau > Y_\tau$ implies corner solutions where complete degradation of the environment may occur. Figure 2.6 depicts this extremely pessimistic view.

Figure 2.6 *Environmentally “at risk” system*



Consider an initial point α_0 , for example. Environmental services are relatively high and output is relatively low. As a country develops, economic growth raises output. If the transition to more appropriate property rights and other forms of environmental protection lags behind, the g isocline does not shift out, and environmental degradation results. As modelled in Figure 2.6, complete

environmental degradation occurs if sufficient time elapses. In this case, the stable solution to (1) occurs at $(0, y_\tau)$.

The condition $y_\tau > Y_\tau$ suggests that the output associated with a zero level of environmental services (y_τ) is relatively large, and that the level of output that drives the growth rate of environmental services to zero (Y_τ) is relatively low. These two conditions conceivably hold for some large developing countries. China, for example, exhibits high output growth rates and is predicted to become the world's largest economy sometime in the next century. It is a labour surplus economy, and if it can maintain relatively high levels of output with few natural resources, then a relatively large y_τ is likely to hold. China's rising national income has had significant adverse impacts on the growth rate of its environmental services, implying that Y_τ , the level of national income at which the growth rate of environmental services falls to zero, could be relatively low.

Such countries are more "fragile" from an environmental perspective. Economic policy might concentrate on green technologies that lift Y_τ above y_τ to help the environment. Technologies that only improve the productivity of "standard" inputs, such as labour and capital, may widen the gap between Y_τ and y_τ .

2.4 The optimistic view: output growth enhancing the environment

2.4.1 Modelling the optimistic view

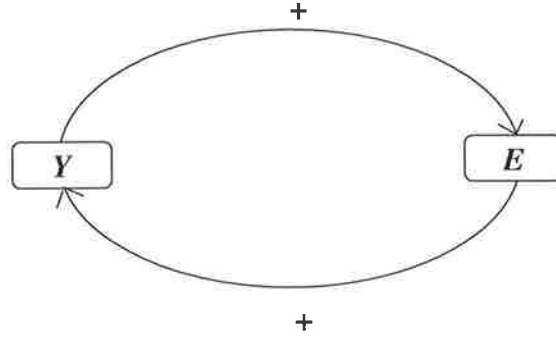
The optimistic view holds that the costs of economic growth to the natural environment are frequently overstated. A number of factors suggest that growth can in fact increase the level of environmental services. Development typically involves a progression through various stages of output composition. These structural shifts eventually lead the economy towards a more environmentally benign composition of output, with a particularly high concentration of resources in service sectors (Baldwin 1994). The second area of change involves the defining and enforcement of property rights. Economic institutions respond to increasing pressures on a limited resource base; the appropriation of scarce resources depends on the effectiveness with which private property rights can be implemented (Radetzki 1992:129). As countries become richer, they tend to develop the advanced political, administrative, legal and social infrastructures necessary to enforce environmental regulation. It seems reasonable to expect property rights to develop along with, or even lead, higher income levels. The extension of private property rights may, in turn, induce the internalization of many negative environmental externalities.

On the consumption side there are also reasons why we might expect output growth to reinforce environmental improvement. A number of changes in consumer behaviour are expected to occur as incomes grow. Since income,

education and declining fertility are highly correlated, the potential threat to ecosystems imposed by population pressures lessens with output growth. Improved levels of education also offer a springboard for environmental research, with improved understanding of environmental problems frequently increasing the desire and capacity to respond to them. Second, there may be a high income elasticity of demand for environmental amenities. On an individual level, consumers with increased incomes may choose to consume more environmentally friendly commodities. On a more aggregate level, as the demand for environmental amenities rises, people will tend to vote for governments reflecting their preferences for more stringent environmental policies (Anderson 1993). For example, an endogenous increase in emission taxes might be expected as countries get richer. A related point is that growth can potentially provide a larger tax base for revenue collection by governments to help fund the environmental objectives of society (Bhagwati 1993).

Empirical evidence lends some support to the possibility of economic growth helping the environment, with emissions of pollutants tending to decline once a certain level of per capita income has been achieved (Grossman and Krueger 1995; Lucas 1996; Radetzki 1992; Selden and Song 1994, Hettige et al. 1998). These views, together with feedback, are summarised in Figure 2.7.

Figure 2.7 Interactions between Y and E : optimistic view



This view of complementarities between output growth and the environment suggests that a different set of assumptions to (A1) will underpin the basic model. We modify the system (1) as follows:

$$\begin{aligned} \frac{dY}{dt} &= F(Y, E, \underline{\tau})Y \\ \frac{dE}{dt} &= K(Y, E, \underline{\tau})E \end{aligned} \tag{4}$$

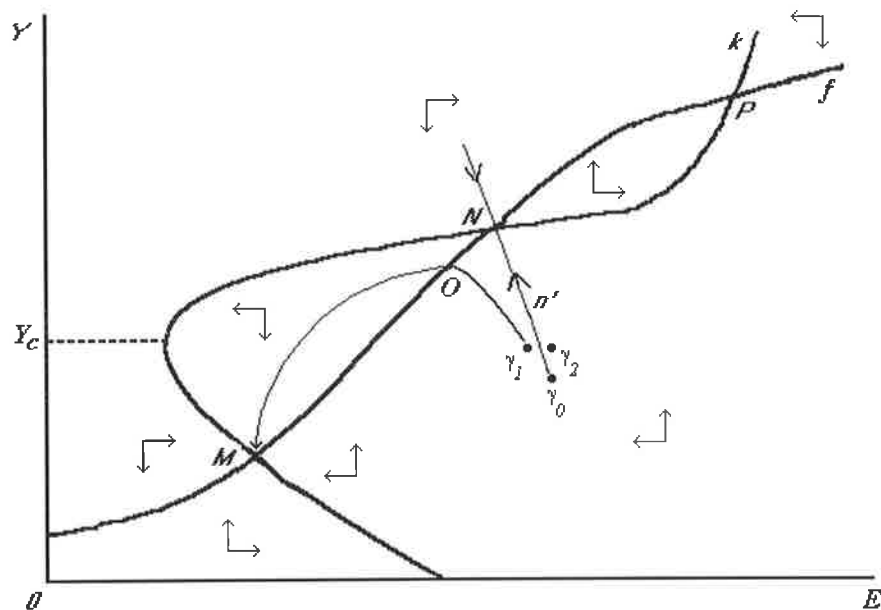
The new assumption set (A2) is:

- (i) $F_Y < 0, F_E > 0, K_E < 0$
- (iia) $K_Y < 0, Y < Y_c$
- (iib) $K_Y > 0, Y > Y_c$

Y_c is the critical value of output at which increases in output augment the growth rate of environmental services. We let $F(Y, E, \underline{\tau}) = 0$ and $K(Y, E, \underline{\tau}) = 0$ implicitly define continuous functions $Y = f(E, \underline{\tau})$ and $Y = k(E, \underline{\tau})$, respectively. These functions are shown in Figure 2.8. Figure 2.8 shows three

interior equilibria. Of the three, N and P occur above Y_c . P is stable while N is a saddlepoint.

Figure 2.8 *Mutual support between output and the environment*



The saddlepoint N is particularly interesting, since environmentalists are often concerned with the potential fragility of an ecological system. Consider n' , a stable manifold of N . Near n' , the level of output and of environmental services are sensitive to a small change in E . This follows from Figure 2.8. Paths at a point such as γ_2 lead to the stable equilibrium at P , while paths starting to the left (such as from γ_1) lead to M . The implication is clear: seemingly small increases in environmental degradation may have damaging consequences for the equilibrium level of output and of environmental quality, even when the environment and output are mutually supportive. This provides some theoretical

support for the hypothesis that cumulative or threshold effects, such as at point O , may drive a reduction in environmental services.

Policies generating an upward shift in f would counter this adverse outcome. If the new saddlepoint were to lie sufficiently to the left of N , then γ_2 would lie to the right of the new stable manifold associated with the saddlepoint. Hence, the trajectory from γ_2 would lead to a stable equilibrium with output and environmental service levels higher than at P . A similar result would hold for policies which induced a rightward shift in k .

2.4.2 Comparative dynamics: Shifting the isoclines

The last point foreshadowed the role of policies or technologies τ_i that shift the isoclines. The shifts determine equilibrium changes in Y and E . We now confine the analysis to the case where there are mutually supportive interactions between Y and E . In particular, we conduct the comparative dynamics from the stable equilibrium point P . (The stability of P is straightforward to establish.)

Let $Y = j_1(\underline{\tau})$, $E = j_2(\underline{\tau})$ represent the stable solutions at P . We now determine the impact of small changes in technology on the solutions.

Lemma 4 Consider the system (4) with assumptions A2(i) and A2(iib). Let $Y = f(E, \underline{\tau})$, $Y = k(E, \underline{\tau})$ be solutions to $F = 0$ and $K = 0$, respectively. For a technology parameter τ_i :

$$\frac{\partial E}{\partial \tau_i} > 0 \Leftrightarrow \frac{\partial k}{\partial \tau_i} < \frac{\partial f}{\partial \tau_i} \quad (5)$$

$$\frac{\partial Y}{\partial \tau_i} > 0 \Leftrightarrow \frac{\partial k^{-1}}{\partial \tau_i} > \frac{\partial f^{-1}}{\partial \tau_i} \quad (6)$$

where f^{-1}, k^{-1} are defined such that $f(f^{-1}(Y, \underline{\tau}), \underline{\tau}) = Y$, $k(k^{-1}(Y, \underline{\tau}), \underline{\tau}) = Y$.

Proof By the implicit function theorem, as $Y = j_1(\underline{\tau}), E = j_2(\underline{\tau})$ are solutions to $F = K = 0$, then:

$$\begin{bmatrix} \frac{\partial j_1}{\partial \tau_i} \\ \frac{\partial j_2}{\partial \tau_i} \end{bmatrix} = \begin{bmatrix} \frac{\partial Y}{\partial \tau_i} \\ \frac{\partial E}{\partial \tau_i} \end{bmatrix} = \frac{1}{F_Y K_E - K_Y F_E} \begin{bmatrix} F_E K_{\tau_i} - K_E F_{\tau_i} \\ F_{\tau_i} K_Y - F_Y K_{\tau_i} \end{bmatrix}.$$

$$\frac{\partial E}{\partial \tau_i} = \frac{F_{\tau_i} K_Y - F_Y K_{\tau_i}}{F_Y K_E - K_Y F_E} > 0 \text{ if } F_{\tau_i} K_Y - F_Y K_{\tau_i} < 0 \text{ and}$$

$$F_Y K_E - K_Y F_E < 0.$$

At point P , since k cuts f from below, it follows that:

$$\begin{aligned}
& \left. \frac{\partial k}{\partial E} \right|_p > \left. \frac{\partial f}{\partial E} \right|_p \\
& \Leftrightarrow \frac{-K_E}{K_Y} > \frac{-F_E}{F_Y} \\
& \Leftrightarrow F_Y K_E - K_Y F_E < 0, \\
& \therefore \frac{\partial E}{\partial \tau_i} > 0 \text{ iff:} \\
& F_{\tau_i} K_Y - F_Y K_{\tau_i} < 0 \\
& \Leftrightarrow \frac{-F_{\tau_i}}{F_Y} > \frac{-K_{\tau_i}}{K_Y} \\
& \Leftrightarrow \frac{\partial f}{\partial \tau_i} > \frac{\partial k}{\partial \tau_i}.
\end{aligned}$$

The second result follows similarly.

Given that the system is mutually supportive, it follows that a parameter change that only increases output ($\partial f / \partial \tau_i > 0, \partial k / \partial \tau_i = 0$) will raise the equilibrium levels of both Y and E .² (The f curve shifts upward/leftward.) Similarly, any parameter change that enhances the growth rate of environmental services (shifting k to the right) will increase the equilibrium levels of Y and E . A parameter change that shifts both curves in the manner described also must increase the equilibrium values of Y and E .

² Trade reform is an example of a policy change that might increase output.

Depending on the magnitude of the upward/leftward shift of the f isocline, and the leftward shift of k , a dirty technology can increase both output and the environment. On the other hand, a dirty technology in this mutually supportive system also has the potential to decrease the equilibrium levels of both Y and E . (In the pessimistic case, by contrast, a dirty technology could help or hinder output, but always at the expense of the environment.)

Green policies can cause the equilibrium levels of both Y and E to fall. Note, however, that different shifts of f and k under a green policy could lead to equilibrium increases in both Y and E . (In the pessimistic model, a green policy which shifted the f curve down/rightward and k upward/rightward unambiguously helped the environment, with the impact on output indeterminate.)

2.5 Conclusions

The theoretical foundations for negative and positive environmental impacts arising from economic growth have been developed in the dynamic model in this chapter. We have demonstrated the potential importance of incorporating feedback effects when modelling economic growth and environmental degradation.

Given the interactive models presented in this chapter, we are able to derive policy-driven outcomes under various assumptions to provide broad policy

guidance. For example we find that an output increasing technology such as trade reform will lead to more output, but has ambiguous effects on the environment, depending on whether the pessimistic or optimistic model holds. In addition, output projections that fail to take the environment into account can overstate the impact on output. This is because the change in output harms the environment, which feeds back to impede the overall increase in output.

More specific policy analysis will however be necessary in many cases. A general equilibrium framework can capture the impacts of finite resources shifting between sectors, and specific policy options can be analysed by examining their impact on various sectors and regions. The following chapters augment a computable general equilibrium (CGE) model to take environmental consequences more explicitly into account. Chapter Three introduces feedback effects for land degradation and Chapter Five uses environmental side-models to project changes in environmental degradation.

3. TRADE LIBERALIZATION AND LAND DEGRADATION IN INDONESIA¹

3.1 Introduction

Land degradation² may have significant adverse effects on productivity, particularly in developing countries. Estimates of land damaged or lost for agricultural use through soil degradation range from “moderate through to apocalyptic” (World Bank 1992a, p. 55). Surveys of country studies on the crop productivity effects of land degradation underline the potentially serious consequences of land degradation (Scherr and Yadav 1996; Pinstруп-Anderson and Pandya-Lorch 1994; Rosegrant and Ringler 1997). For example, in countries such as Costa Rica, Malawi, Mali and Mexico, soil erosion is estimated to cause national economic losses of between 0.5 and 1.5 percent of annual GDP (World Bank 1992a). Countries with fragile tropical land are particularly problematic, and rural poverty in developing countries may force people with no other options to exploit available resources beyond their sustainable capacity (Pinstруп-Anderson and Pandya-Lorch 1994).

For Indonesia, soil erosion appears to be one of the most significant environmental problems caused by agricultural production. Although soil

¹ This chapter is a revised and extended version of Strutt (1998).

² A temporary or permanent decline in the productive capacity of land (Scherr and Yadav 1996, p. 3).

erosion does not appear to have a major impact on land productivity in countries such as the US, it may be a far greater problem for tropical countries. For example, average erosion rates in the US are estimated at about 0.7 tons of soil/ha/yr. This compares with overall erosion rates in Java of around 6-12 tons/ha/yr on volcanic soils and much higher losses on limestone soils and agricultural land (World Bank 1990). The high erosion rates are mainly due to the level and intensity of tropical rainfall, and the loss of ground cover on steep terrain.

World Bank estimates suggest that soil erosion on Java costs the economy US\$340-406 million per year in 1989 dollars (Magrath and Arens 1989). Of this, nearly 80 percent is due to declines in the productivity of agricultural land. The other 20 percent or so is due to off-site costs such as siltation of irrigation systems and the loss of reservoir capacity. The estimated cost of soil erosion for Java is approximately 0.4 percent of total GDP or 2 percent of agricultural GDP (Magrath and Arens 1989; World Bank 1994).³ This is significant for a country that has achieved only a little over 2 percent average annual growth in agricultural production so far this decade.⁴

Chapter Two demonstrated the potential importance of including environmental damage feedback effects when considering policy changes. This chapter extends the Global Trade Analysis Project (GTAP) model to include the effects of land

³ However Lindert (1996) finds that there is virtually no evidence of productivity loss over many decades of net soil degradation in Indonesia. It is possible that farmers respond to minimize the effects of erosion by increasing other inputs such as fertilizer.

degradation for the Indonesian economy. We simulate off-site environmental damage and on-site productivity impacts, along with the more standard intersectoral and interregional economic effects of Uruguay Round trade reform. The contribution of this chapter is to quantify the welfare implications of trade policy changes for a large developing country, where soil erosion occurs and land productivity is reduced.

3.2 Modelling land degradation in Indonesia

3.2.1 Land degradation

The environmental links of agricultural production are two-way. Agricultural production affects environmental quality and environmental quality affects agricultural production. There are many interrelated variables and feedback effects, and measurement of even the major environmental effects is not an easy task (see Appendix A). We keep the task manageable by concentrating on developing environmental damage functions for land. These are used with a modified version of the GTAP model to examine external costs and the degradation of land caused by soil erosion in Indonesia.

As farmers increase their production, they tend to generate more erosion. The erosion damage can cause on-site productivity losses or off-site environmental damage. Farmers may respond to the on-site productivity effects (Barrett 1991),

⁴ 1990-1996 as calculated from the agricultural production index provided in the FAO database

but are unlikely to take the non-marketed off-site impacts of their activities into account when they make decisions if there are no incentives to do so. We model both off-site environmental damage and on-site productivity effects. We also make small modifications to the standard modelling of land in GTAP to enable land to shift between agriculture and forestry. The modifications we make involve minimal changes to the standard version of GTAP to retain the structure of the model and ensure that the consistency of the benchmark data is preserved. We exploit available environmental data without introducing a large number of parameters for which no appropriate data exists.

3.2.2 Transformation of land between sectors

There is currently no land allocation to forestry in GTAP Version 3. However, it appears likely that land does shift between the forestry and agricultural sectors (World Bank 1990, Southgate 1990).⁵ We adjust the standard database to allocate some returns to forestry land in Indonesia. Returns to land are based on 50% of value added; this is similar to the value added by land for most other agricultural sectors in GTAP.

GTAP models land as an imperfectly mobile factor of production with the mobility described by a constant elasticity of transformation (CET) function (Powell and Gruen 1968; Hertel and Tsigas 1997). The CET revenue function is

(FAO 1997).

⁵ There is some dispute about the extent to which agricultural extensification causes deforestation. But even if it is not the *major* cause (World Bank 1994), it is still likely to be significant (World Bank 1990 and Southgate 1990).

analogous to the constant elasticity of substitution (CES) cost function, but with an Allen partial elasticity of substitution less than zero. This restricts mobility and enables productivity differences between land used in different farm sectors, with land measured in productivity units rather than hectares (Darwin et al. 1995). We retain the standard GTAP elasticity of transformation function with an elasticity of substitution of -1 for all land-using sectors, including forestry.

3.2.3 Off-site environmental damage

For resources with no stock feedback effects, environmental degradation can be modelled either as a factor of production (López 1994), or as a joint product in output (Copeland 1994, Tobey and Reinert 1991). Off-site effects are modelled here as driven by the level of production inputs and technology in the environmentally degrading sector.

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

$$D = \sum_{i=1}^n E_i \quad (1).$$

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

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

where

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

The term e_j indicates the proportional change in erosion. This method of calculating environmental damage follows the innovative work of Coxhead and others (Coxhead and Shively 1995; Bandara and Coxhead 1995 and Coxhead 1996). When used with the GTAP model, it has the important advantage of only requiring estimates of β_j (the share of total erosion contributed by each sector in the benchmark year). All other data and parameters necessary to determine the change in erosion are available in the standard GTAP database. Large changes to the core model and database are therefore unnecessary.

For the non-marketed effects of off-site environmental externalities, we append damage functions to the standard GTAP model. We use these side-equations to calculate the change in total erosion and the resulting off-site damage caused by shifts in land use. Once we have estimated the change in erosion, we estimate the welfare costs of the non-marketed off-site effects.

Magrath and Arens (1989) estimate the annual off-site damage caused by erosion for *Java* to be in the range of US\$25.6m to US\$91.2m.⁶ However we need estimates of the total off-site erosion costs for *Indonesia* for 1992. Agricultural production is thought to be an important determinant of erosion. We use this as a proxy to scale up the costs of erosion from Java alone to the whole country. We derive estimates of the contribution of each region to production from a 1993 disaggregated social accounting matrix for Indonesia (Warr and Azis 1997, Table 7). Table 3.1 shows the relative contribution of Java (Region 1) to total agricultural crop and forestry production. The final row of Table 3.1 indicates that Java contributes approximately 50 percent to total agricultural crop and forestry production in Indonesia. We therefore estimate the total off-site costs of erosion in Indonesia to be in the order of double the costs for Java alone. With inflation of almost 10 percent in 1990 and 1991 (McLeod 1997, p. 199), this places the off-site erosion costs for Indonesia in the range of US\$62m to US\$220m in 1992 dollars. It is hoped that this range provides some indication of the magnitude of off-site erosion costs for Indonesia. Other factors such as the steepness of slopes, different soil types and high forestry production in regions other than Java may increase this estimate. However, the impact on reservoir siltation and irrigation systems is likely to be lower in the less populated areas outside Java, where there is lower emphasis on irrigated rice production.

⁶ The off-site costs valued include the siltation of irrigation systems, the obstruction and dredging of ports, and reservoir siltation.

We use the high estimate of US\$220m per annum to value the cost of off-site erosion in Indonesia. This is partly a cautionary approach, but also the cost estimates may be understated since they do not include all of the potential costs of off-side damage, such as the cost of flooding and stream flow irregularities (Magrath and Arens 1989).⁷

3.2.4 On-site adverse productivity effects

Production feedback effects are modelled to capture the adverse impact of on-site soil erosion on land productivity. We capture the effect of land degradation in our modified version of the GTAP model through use of a land quality shifter parameter, FB_f^j .⁸ As land quality deteriorates due to erosion, additional units of land (and other primary factors) are required to sustain the same level of output. Use of this feedback parameter mimics the deterioration in land quality and productivity when erosion occurs.

We can now derive sector j 's demand for primary factors in the presence of erosion. Three primary factors of production are identified in the GTAP Version 3 database: land, labour, and capital. These primary factors combine according to a CES production technology, which is used to describe substitution possibilities between units of primary factors in sector j . The resulting *effective*

⁷ Studies for other regions have sometimes found the total off-site costs of erosion to be of much higher magnitude than on-site losses in production (Crosson 1986).

⁸ This is very similar to an exogenous factor-specific technical change variable (though erosion and the associated FB_f^j could be determined endogenously within the model if suitable data were available).

primary factor input for sector j is then combined with intermediate inputs to form the production capability of sector j .

Given the price of primary factor f in sector j (P_f^j), profit maximizing producers choose the least cost combination of primary factor inputs of type f (X_f^j) necessary to sustain a given level of production (Z^j). Producers minimize:

$$\sum_{f=1}^3 \bar{P}_f^j X_f^j \quad j = 1, \dots, n \quad (3)$$

subject to a CES production function

$$Z^j = A \left[\sum_{f=1}^3 \delta_f \bar{X}_f^{-\rho} \right]^{-1/\rho} \quad (4)$$

where

$$\begin{aligned} \bar{X}_f^j &= \frac{X_f^j}{FB_f^j} \\ \bar{P}_f^j &= FB_f^j P_f^j \end{aligned} \quad (5)$$

A and δ_f are positive parameters with $\sum_{f=1}^3 \delta_f = 1$. ρ is a parameter greater than or equal to -1 ; as it approaches zero, it approaches a Cobb-Douglas form. $\bar{X}_f^j$ is the effective land input (Dixon et al. 1982, pp. 76-81 and 1992, pp. 125-6).

The Lagrangian function is:

$$L = \sum_{f=1}^3 \bar{P}_f^j \bar{X}_f^j + \Lambda \left(Z^j - CES(\bar{X}_f^j) \right)$$

where Λ is the Lagrange multiplier. The first order conditions for this cost minimization problem are:

$$\bar{P}_f^j = \Lambda A \left[\sum_{i=1}^3 \delta_i \bar{X}_i^{-\rho} \right]^{-(1+\rho)/\rho} \delta_g \bar{X}_g^{-(1+\rho)}$$

and

$$L_\Lambda = Z^j - CES(\bar{X}_f^j) = 0$$

$$\text{i.e. } Z^j = A \left[\sum_{i=1}^3 \delta_i \bar{X}_i^{-\rho} \right]^{-1/\rho}$$

These conditions are solved to determine the primary factor demand equation which is expressed in linear percentage change form as (Dixon et al. 1992, p. 125):

$$\bar{x}_f^j = z^j - \sigma_f^j \left(\bar{p}_f^j - \sum_{f=1}^3 S_f^j \bar{p}_f^j \right). \quad (6)$$

Lower case letters are used to indicate the percentage change in the corresponding upper case variables. Applying the percentage change forms of the two equations in (5), we find the primary factor demand:

$$x_f^j = z^j + fb_f^j - \sigma_f^j \left(p_f^j - \sum_{f=1}^3 S_f^j p_f^j \right) - \sigma_f^j \left(fb_f^j - \sum_{f=1}^3 S_f^j fb_f^j \right) \quad (7)$$

where

$$\sigma_f^j = \frac{1}{1 - h_f^j}$$

$$S_f^j = \frac{\delta_k X_k^{-\rho}}{\left(\sum_i \delta_i X_i^{-\rho} \right)}$$

and

x_f^j = demand for primary factor f by sector j

z^j = activity level in sector j

fb_f^j = primary factor f -augmenting feedback

σ_f^j = elasticity of substitution between primary factors in sector j

p_f^j = unit price or rental rate for primary factors used by sector j

S_f^j = share of primary factor costs in sector j accounted for by the cost of primary factor f .

Equation (7) relates each sector's demand for primary factors to the overall activity level in the sector, to the costs of different types of primary factors, and to the feedback variable. Equation (7) indicates that if land degradation causes a one percent increase in the land-specific feedback variable (fb_i^j), then the requirement of land by sector j increases by $\left(1 - \sigma_l^j (1 - S_l^j)\right)$ in order to sustain the

given level of activity level.⁹ Such a reduction in the quality of land will also induce substitution away from land toward the other two primary factors (Dixon et al. 1982, p. 82).

The effects of the feedback variable outlined above necessitate some changes to the standard GTAP model and parameters. In the GTAP model, the equivalent of equation (7) appears as two types of equations. The first describes substitution among inputs within a nest. Its form follows directly from the CES form of the production function. The second type of equation is the composite price equation which determines the unit cost for the composite good produced by that branch (Hertel and Tsigas 1997). We adapt both of these equations to incorporate feedback effects. The decomposition equations appended to the standard model (Huff and Hertel 1996) are also changed to capture the impact of the feedback variable when decomposing welfare changes. This procedure for incorporating environmental damage more explicitly into the GTAP model could be generalized to include other forms of environmental damage, and also the situation where damage caused by one sector adversely affects other sectors.

For Indonesia, we assume that the adverse effects of on-site soil erosion cause a reduction in land productivity in some agricultural sectors. Repetto et al. (1989) calculate average productivity losses to be 6.8 percent on erosion-sensitive crops such as maize and 4.3 percent on less sensitive crops such as cassava. We follow this work and assume that the grain sector exhibits a 6.8 percent reduction in land productivity. The non-grain crops sector includes staple and estate crops.

⁹Assuming that factor prices are constant.

We assume that 50 percent of the crops are erosion-sensitive, which leads to a 5.6 reduction in land productivity for the non-grain crop sector. No adverse productivity effects are assumed for other agricultural and forestry sectors.

3.3 Effects of Uruguay Round trade liberalization

3.3.1 Modelling Uruguay Round implementation

We model the effects of multilateral trade liberalization using a general equilibrium model closure. This closure captures the changes in trade flows and the substitution in production and consumption that occurs between commodities. Prices, output levels and incomes are endogenous for all regions. Policy variables, factor endowment levels and technical change variables are exogenous. We aggregate the full 30 region, 37 sector Version 3 GTAP database to 6 regions and 17 sectors. The regional aggregation includes Indonesia, China, high income APEC economies, developing APEC economies, the other high income countries of Western Europe and the rest of the world's developing and transition economies. Tables 3.2 and 3.3 detail the regional and commodity aggregation. The model is implemented and solved using GEMPACK (Harrison and Pearson 1996).

A Uruguay Round-type trade liberalization is simulated from the GTAP 1992 base.¹⁰ Cuts to tariff rates, agricultural export subsidies and elimination of the Multifibre Arrangement (MFA) quotas are needed to generate a credible post-Uruguay Round environment from the GTAP protection data (McDougall 1996). Using protection vectors that draw on extensive work by the World Bank (McDougall 1997), we lower tariffs to post-Uruguay Round levels. Appendix C reports the pre- and post-Uruguay Round average tariff rates for Indonesia. The export tax equivalents of MFA quotas are removed and agricultural export subsidies are also reduced. We assume that agricultural export subsidies are reduced by 36 percent in developed economies (see Chapter Four for more details).

When protection is reduced, interregional and intersectoral shifts in economic activity affect welfare. Table 3.4 shows the projected effect of Uruguay Round trade liberalization on welfare. Projected changes in economic welfare, as measured by an equivalent variation in income, are shown in the first row. The welfare measures incorporate the effect of on-site environmental damage on land productivity. To prepare these results, we run a simulation with just the land productivity effects. Including land degradation in the model will affect the benchmark data, even with no policy changes. The difference between these results and the the Uruguay Round simulation (including land productivity

¹⁰ See Chapter Four for a similar Uruguay Round-type liberalization but which is assumed to be phased in over the period prior to 2010.

¹¹

effects) allows us to isolate the results due to trade liberalization, in the presence of land degradation.

Uruguay Round trade liberalization is projected to increase welfare for Indonesia by US\$1,018m. The welfare effects can be decomposed into four components (see Table 3.4): allocative efficiency effects (Huff and Hertel 1996), terms of trade effects (McDougall 1993), on-site productivity effects and off-site environmental damage.¹² Allocative efficiency gains result when resources are reallocated into areas of more efficient production. As shown in the second row of Table 3.4, Indonesia experiences significant gains of US\$833m in allocative efficiency. Of this gain, US\$635m is due to improved allocative efficiency in the textile, leather and wearing apparel market when Indonesia reaps the benefits of MFA quota elimination. The contribution to welfare of changes in the terms of trade are reported to be US\$180m in row 4. The inclusion of on-site productivity effects for changes in land use in Indonesia appears to cause a positive, albeit extremely small, change in welfare with trade reform. Row 4 of Table 3.4 shows that the productivity effects contribute 0.4 percent to the welfare gain from Uruguay Round liberalization for Indonesia. This small positive contribution to welfare is driven by the reduction in production, and land degradation, in the large non-grain crop sector. Off-site environmental damage increases and leads to a small reduction in welfare of less than 0.15%. This effect is discussed further in the following section.

¹² The summation of these effects may not equal the total change in welfare reported due to marginal utility of income effects. The effects are small in this simulation and simply reflect the non-homothetic preferences assumed in the standard version of GTAP (Huff and Hertel 1996).

3.3.2 Change in erosion and off-site damage

Table 3.5 presents the assumptions used to calculate β_j , the share of total erosion contributed by each sector in the benchmark year. The first column shows estimates of area harvested in each agricultural sector in 1992 derived from FAO data (FAO 1997). Area harvested for forestry is calculated from Duchin et al. (1993, p. 95).¹³ Erosion rates for each sector are approximations that can be improved as further data becomes available and as the available sectoral disaggregation of the GTAP database improves. We estimate the average erosion rates shown in column 2 from more detailed information presented in Magrath and Arens (1989), Duchin et al. (1993) and Repetto et al. (1989). No erosion is assumed in the paddy rice sector. Apart from the short-term erosion that occurs during the establishment of new ricefields, soil erosion does not appear to be an important issue for irrigated rice production (Duchin et al. 1993, p. 63). Within the non-grain crop sector, estate crops have a significantly lower erosion rate since they are predominantly tree crops. Columns 1 and 2 multiplied together give an indication of the total erosion contributed by each sector.

To examine the off-site environmental damage of soil erosion in Indonesia, we analyse changes in land use. In particular, we examine the shift of land between crops with different rates of soil erosion. Table 3.6 reports the projected change in erosion following trade liberalization. The first column shows the initial

erosion share for each sector. These are the percentage shares in total erosion calculated from Table 3.5. The simulated change in land use is reported in column 3 of Table 3.6. The final column indicates the resulting aggregate change in erosion. Our simulation projects a 0.69 percent increase in aggregate erosion in Indonesia following Uruguay Round liberalization. Although land use is reduced by almost one percent in both the non-grain crop and the forestry sectors, it increases by almost three percent in the coarse grains sector. The coarse grain sector is a relatively small sector, but it has a high rate of erosion which drives this result.

Given the existing off-site costs of erosion of US\$220m we estimated in Section 3.2.3, the 0.69% increase in soil erosion projected here suggests an increase in off-site erosion costs of US\$1.5m for Indonesia. Despite using a high estimate of off-site costs, this still represents less than 0.15 percent of the projected increase in welfare due to Uruguay Round trade liberalization. Furthermore, the erosion increase may be overstated since the comparative statics ignore important long run effects and political benefits.¹⁴

¹³ Forestry output is 24082 thousand cubic metres and average yield of production forest is 21.2 cubic metres/ha. If annual deforestation is used instead, the figure is very close, with 1212 thousand ha annually (World Resources Institute 1994, p. 307).

¹⁴ For example, as world incomes grow, there may be a global improvement in soil caused by the shift away from producing staples, especially staple grains (Lindert 1996). In addition, significant erosion problems are caused by poor households with high discount rates seeking to increase immediate food production by using cropping methods that result in high soil erosion levels from their rainfed lands (Barbier 1990). Increased incomes may reduce these problems. And as land tenure becomes more secure, farmers may guard the productive capacity of their land more carefully.

3.3.3 Systematic sensitivity analysis

In a simulation such as that presented here, results often hinge crucially on the values of key exogenous inputs. When precise information is not available, as in the case of land productivity changes, it may be more appropriate to specify distributions rather than point estimates. Systematic sensitivity analysis (SSA) is an emerging technique that can incorporate information on distributions, as opposed to single point estimates, in computable general equilibrium models. Arndt (1996) developed the SSA technique from recent advances in the area of numerical integration and its application to economic problems (DeVuyst and Preckel 1997). The procedure automates solving the model as many times as is necessary (Arndt and Pearson 1996).

We conduct SSA analysis on the land productivity feedback parameters used in this chapter. Symmetric triangular distributions are assumed: for coarse grains a mean of -6.8 and a minimum value of -13.6 are used; for non-grain crops a mean of -5.55 and a minimum value of -11.1 are used. The welfare results appear fairly robust to the assumptions we make for the on-site productivity effects of soil erosion. For example, the mean of the equivalent variation in income from Uruguay Round implementation is US\$1,018 million, and the standard deviation is US\$130 million. Thus even with the possibility of relatively high land productivity losses, we do not expect to see much erosion of the substantial gains from Uruguay Round implementation.

3.4 Conclusions

The inclusion of erosion and land degradation in a global trade model enables a fuller welfare analysis of the effects of economic policy changes. We find that with Uruguay-Round trade liberalization, the level of production and soil erosion rises in the coarse grain sector but falls in the non-grain crops and forestry sectors. Net land productivity changes appear to be positive, since a reduction in land use in the large non-grain crops sector should improve land productivity.

Results for the non-marketed off-site effects of erosion suggest that there may be a small increase in soil erosion in Indonesia with trade liberalization. This is due to increased land use in the relatively erosive coarse grain sector. However, relative to the projected gain from trade liberalization, the cost of damage caused by increased erosion appears very low (less than 0.15 percent of the welfare gain from trade liberalization for Indonesia). Systematic sensitivity analysis of the key environmental parameters indicates these results are fairly robust to assumptions about land productivity losses.

Measuring the environmental impacts of economic policy reform is not an exact science, particularly given the paucity and uncertainty of much environmental data. However, transparent modelling opens issues to debate and seems an appropriate means of improving our understanding while helping to provide estimates of the orders of magnitudes involved, given incomplete information. This chapter makes some of the trade-offs between income growth (from trade

reform) and environmental damage more explicit. It complements micro-level studies which will be better able to identify regions and crops facing large and irreversible erosion effects.

Table 3.1: Contribution of each region to agricultural production in Indonesia by sector (%)

	<i>Region 1^(a)</i>	<i>Region 2^(b)</i>	<i>Region 3^(c)</i>	<i>National Total^(d)</i>
Paddy rice	63	14	25	100
Coarse-grains	57	18	26	100
Non-grain crops	53	26	20	100
Forestry	3	11	84	100
Total agricultural and forestry	49	20	31	100

^(a) DKI Jaya, West Java, DIY Yogyakarta, Central Java, East Java and Bali.

^(b) DIY Aceh, North Sumatra, West Sumatra, Riau, Jambi, Bengkulu, South Sumatra, Lampung.

^(c) West Nusa Tenggara, East Nusa Tenggara, East Timor, West Kalimantan, Central Kalimantan, East Kalimantan, South Kalimantan, South Sulawesi, North Sulawesi, Central Sulawesi, Southeast Sulawesi, Maluku and Irian Jaya.

^(d) May not quite sum to 100 due to rounding.

Source: Derived from Warr and Azis (1997, Table 7).

Table 3.2: Regional aggregation

<i>Regional Aggregation</i>	<i>GTAP Aggregation</i>
Indonesia	Indonesia
China	China
Industrialised APEC economies	Australia New Zealand United States Canada Japan Hong Kong Singapore Taiwan
Developing APEC economies	Korea Thailand Malaysia Philippines Mexico Chile
Other high income countries of Western Europe	European Union-12 EU-3 (Austria, Finland and Sweden) EFTA (Iceland, Norway, Switzerland)
Rest of the world's developing and transition economies	Argentina Brazil Rest of South America Central America and the Caribbean India Rest of South Asia (Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka) Middle East and North Africa Sub Saharan Africa Central European Associates (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) Former Soviet Union Rest of World

Table 3.3: Commodity aggregation

<i>Aggregated Commodity</i>	<i>GTAP Commodity</i>
Paddy Rice	Paddy rice Processed rice
Wheat	Wheat
Coarse grains	Coarse grains
Non-grain crops	Non grain crops
Livestock	Wool Other livestock Meat products Milk products
Forestry	Forestry
Fisheries	Fisheries
Coal, oil and gas	Coal Oil Gas
Other minerals	Other minerals
Food processing	Other food products Beverages and tobacco
Textiles	Textiles Wearing apparels Leather etc.
Wood and paper products	Lumber Pulp paper etc.
Petroleum and coal	Petroleum and coal
Chemicals, rubber and plastics	Chemicals rubbers and plastics
Non-metallic minerals	Non-metallic minerals
Other manufactured products	Primary ferrous metals Non-ferrous metals Fabricated metal products Transport industries Machinery and equipment Other manufacturing
Services	Electricity water and gas Construction Trade and transport Other services (private) Ownership of dwellings Other services (govt.)

Table 3.4: Welfare effects of Uruguay Round liberalization for Indonesia

Welfare indicator	Change US\$m
Change in welfare	1,018
Allocative efficiency effects	833
Terms of trade effects	180
On-site productivity effects	4
Off-site productivity effects	-1.5

Source: Authors' model results.

Table 3.5: Calculations for erosion contributions of agricultural and forestry sectors in Indonesia

	(1)	(2)	(3)
	<i>Area Harvested</i>	<i>Erosion Rate</i>	<i>Quantity of Erosion</i>
	<i>(000 ha)</i>	<i>(t/ha/annum)</i>	<i>(million tonnes)</i>
Paddy Rice	11,103	0	0
Grain	3,629	100	363
Non grain crops Staple crops	3,457	100	346
Estate crops	10,404	4.3	45
Forestry	1,136	80	91

Source: Authors' calculations, drawing on FAO (1997), Magrath and Arens (1989), Duchin et al. (1993) and Repetto (1989).

Table 3.6: Change in soil erosion in Indonesia from Uruguay Round implementation

	(1)	(2)	(3)
Sector	Initial erosion share (%)	Change in land use (%)	Change in erosion (%)
Coarse grains	43	2.79	1.20
Non-grain crops	46	-0.93	-0.43
Forestry	11	-0.78	-0.09
Total	100	0	0.69

Source: Authors' model results and Table 3.5, column 3.

4. STRUCTURAL AND TRADE POLICY CHANGE IN INDONESIA: 1992-2020¹

4.1 Introduction

Rapid economic development and trade reform will have far-reaching consequences for Indonesia in coming decades. This chapter uses the Global Trade Analysis (GTAP) model to project the standard economic implications of structural change and economic policy reforms. The implications for the natural environment of these structural and trade policy changes are postponed to Chapter Five.

We project economic growth and structural change for the periods 1992-2010 and 2010-2020.² We also model Uruguay Round and APEC liberalization over these periods. The Uruguay Round agreement should be fully implemented by 2005, before the end of the first period. 2010 is the agreed date for completion of APEC trade liberalization by industrialised countries. The period to 2020 covers the full span of Indonesia's Second Long Term Development Plan. It also marks the date agreed at Bogor in November 1994 for completion of trade liberalization by Indonesia and other developing country members of APEC.

¹ This chapter is a revised and extended version of Strutt (1997a).

The contribution of this chapter is to model the impact of structural change and trade reform in Indonesia over almost three decades. Previous studies of trade reform for Indonesia using the GTAP model have projected trade liberalization from the benchmark 1992 database (for example, Stephenson and Erwidodo 1995, Erwidodo and Feridhanusetyawan 1997 and Feridhanusetyawan 1997). Anderson and Pangestu (1998) use a more appropriate approach by projecting the GTAP database to 2005 before simulating the trade liberalizations. Their work is also differentiated from previous studies by the use of a carefully constructed set of Uruguay Round shocks that draw on extensive work by the World Bank. This chapter extends the work by projecting the world economy to 2010 and 2020 before simulating the appropriate trade reforms. Our new projections enable a view of the Indonesian economy much further into the future than was previously available. The new projections also facilitate modelling full APEC liberalization, which is scheduled to be completed by 2020.

Section 4.2 discusses the modifications made to the standard version of GTAP for simulating our projections. This version of GTAP differs from that used in Chapter Three because we are now using the model to project several decades into the future and the model needs to be modified to facilitate this. Section 4.3 outlines the key assumptions and the scenarios modelled. It details the exogenous macroeconomic targets and pays particular attention to the

² We abstract here from the current economic and political crisis and assume that long-run growth prospects are not affected. Anderson and Strutt (1998) augment this analysis with

anticipated responsiveness of each sector to changed conditions. Section 4.4 presents the results of structural change projections for 1992-2010 and 2010-2020. Section 4.5 reports the results of trade reform: the impact of Uruguay Round liberalization, both without and with the inclusion of China, is examined first; then the effects of APEC liberalization are analysed.

4.2 Using GTAP for projections

4.2.1 Projecting structural change with GTAP

The GTAP model can be used to address a wide range of comparative-static questions. In this chapter we use it to examine the implications of global economic growth and international trade policy reform.

The GTAP Version 3 database (McDougall 1997) is aggregated for these simulations to aid computation and highlight the implications for Indonesia and for other developing and industrialised APEC economies. The database is aggregated to five regions and 23 sectors. The five regions are Indonesia, other developing APEC economies, high-income APEC economies, the other-high income countries of Western Europe, and the rest of the world's developing and transition economies. Table 4.1 details the regional aggregation,³ while Table 4.2 shows the sectoral aggregation. The model is implemented and solved using GEMPACK (Harrison and Pearson 1996).

modified assumptions that attempt to take into account the current crisis.

Following other recent work using the GTAP model for projections, a small number of exogenous macroeconomic variables are shocked to simulate the effects of growth in the global economy over time. These exogenous shocks drive projections of intersectoral and international economic impacts. We make a number of modifications to the standard version of GTAP for simulating the projections presented in this chapter. Many of these modifications draw on existing work in this area (for example, Bach 1996; Dimaranan 1996; Arndt et al. 1996).⁴ Our modifications include introducing specific factors of production in the natural resource sectors, allowing some land movement between forestry and agriculture, splitting the single factor labour into skilled and unskilled labour, and increasing the Armington trade elasticities. Details of the modifications follow.

4.2.2 Specific natural resource factors and land

The imposition of large exogenous shocks to capital to simulate factor accumulation can create difficulties in the standard version of GTAP, where only three factors of production are specified.⁵ In particular, since natural resource sectors are capital intensive, large exogenous capital shocks may lead to inappropriately large increases in output in these sectors. This follows from the expected Rybczynski effect of increasing endowments: output increases in

³ Full details of the sectoral aggregation mapping to the 61 sector Indonesian input-output table are provided in Appendix B.

⁴ These studies, however, only present projections to 2005.

⁵ Version 4 of the GTAP database will have five factors of production specified.

those sectors using the endowment intensively and output is reduced in other sectors as resources are pulled away. However, in the case of natural resource sectors, some capital is not reproducible and it may not be appropriate to effectively allow unrestrained expansion of these sectors. Capital injections may help in the discovery and appropriation of scarce resources; however, increases in capital cannot fully replace natural resources such as petroleum and minerals.

A specific factor is added in each of the natural resource-based GTAP sectors which dampens what would otherwise be inappropriately large growth in these sectors. The specific factor is modelled in much the same way that the sluggish factor land is modelled in GTAP, but with a restraint placed on its ability to move between sectors.⁶ Specific factors are modelled in the natural resource sectors of forestry, fisheries, coal, oil, gas, and other minerals. In the case of forestry, factor payments are also adjusted to show value added by land in this sector and to enable some movement of land between forestry and agriculture (see Chapter Three for further details).

The global GTAP database is adjusted before being aggregated to the five region, 23 sector version presented here. Sixty percent of the value added by capital in each of the natural resource sectors is assumed to be attributed to a specific factor. This follows a similar assumption made by Arndt et al. (1996).

⁶ The equivalent of the CET elasticity of transformation (ETRAE) is set to almost zero. The quantity response of the specific factor is then effectively zero.

In the case of forestry, it is assumed that half of the factor payments reassigned go to land and the other half to the specific factor (trees in this case).⁷

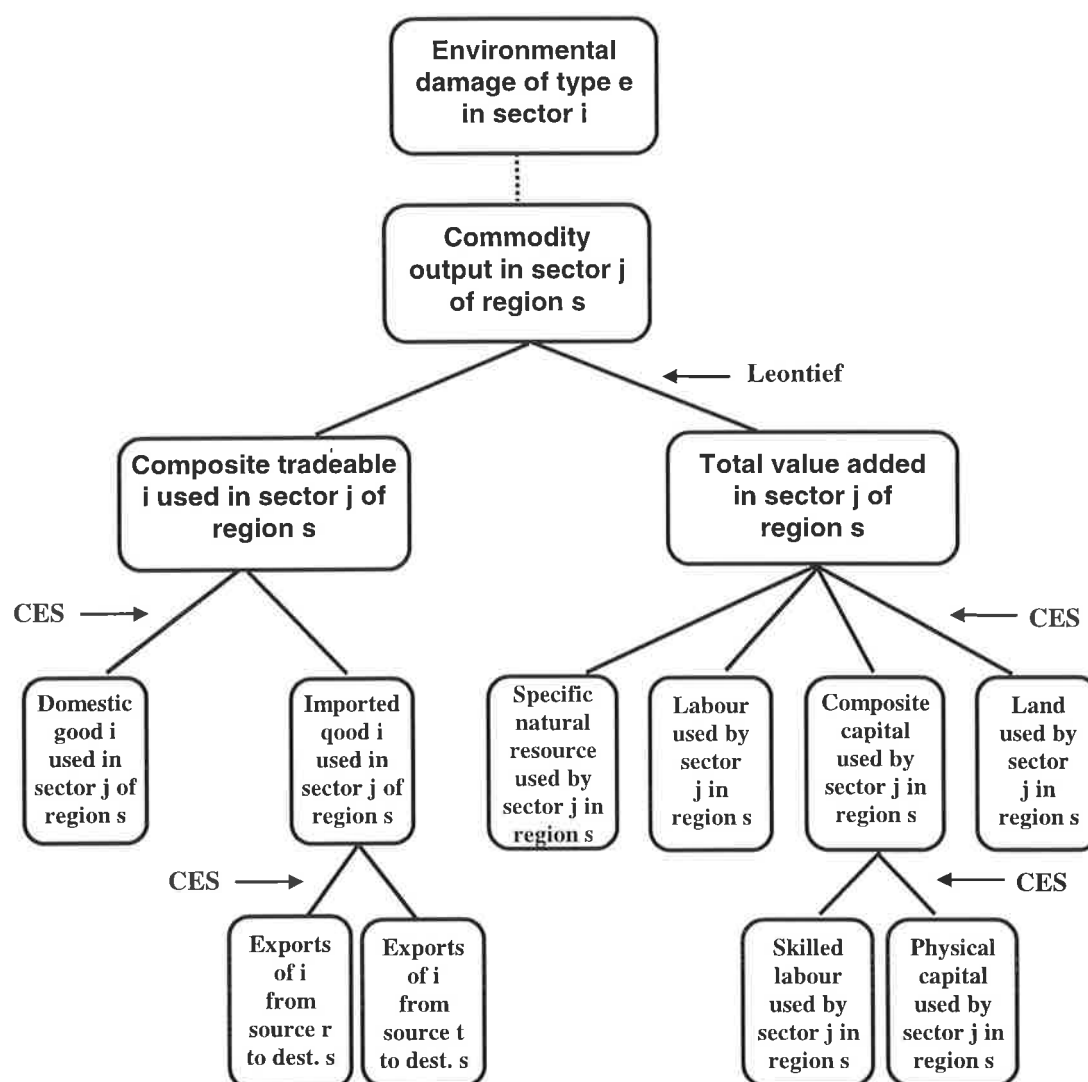
4.2.3 Splitting labour into two components

Gehlhar (1997) shows that breaking labour into two components produced significantly better results in a backcasting exercise for the decade 1992-1982. Therefore, we split the single factor labour in GTAP into skilled and unskilled labour for this work. The global GTAP database is adjusted using recent estimates of labour payments by skill level (Liu et al. 1997, p. 17) and a composite capital nest is created for human and physical capital following Arndt et al. (1996). Table 4.3 provides a detailed sectoral breakdown of factor payments for Indonesia. Table 4.4 summarises the factor payments to all factors of production, including skilled and unskilled labour and the natural resource specific factor.

The modified structure of production is summarised in Figure 4.1, along with the standard functions assumed in GTAP. In particular, producers choose inputs that minimize production costs subject to separable, constant returns to scale technologies. Constant elasticity of substitution (CES) functions describe

⁷ Work is currently in progress by the GTAP team to improve understanding of the returns which may be attributed to specific resources in natural resource-based industries in the GTAP model. This will enable improved assumptions with respect to factor payments in future work.

Figure 4.1 *Structure of production in the modified version of GTAP⁸*



Source: Modification of Figure 2.6, Hertel and Tsigas (1997, p. 39)

substitution possibilities between primary factors. 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.

⁸ A discussion of the environmental damage produced given output and technology is postponed to Chapter Five.

4.2.4 Armington trade parameters

As indicated in Figure 4.1, the GTAP model assumes an Armington structure for imports. They are distinguished by origin and aggregated at the border, where the composite import is distinguished from the domestically produced commodity and the optimal mix is determined. The CES function used is homothetic in total expenditure, implying that the choice between imports and domestic production is independent of the level of income. This is contrary to empirical observations, particularly for rapidly growing Asian countries where the ratio of imports to GDP tends to increase significantly with economic development (Bach 1996). Increasing the Armington elasticities was shown to lead to more accurate simulation results in a backcasting exercise with GTAP (Gehlhar 1997). With this in mind, and following previous work on projecting with GTAP, the Armington elasticities are doubled.¹⁰ Since rigidities in trade flows are expected to diminish over time, this will better facilitate the large exogenous growth shocks involved with projecting long into the future (Arndt et al. 1996).

⁹ A discussion of the environmental damage produced given output and technology is postponed to Chapter Five.

¹⁰ Arndt et al. (1996) conduct systematic sensitivity analysis of the effects of changing Armington elasticities.

4.3 Projecting structural and policy change

4.3.1 Assumptions

In any modelling work, it is important to carefully examine the assumptions made. When projecting several decades into the future, the potential effects of these assumptions are magnified. This section begins with a detailed discussion of the assumptions here and an analysis of how these assumptions will drive results. Section 4.3.2 describes the specific simulations conducted.

To project future changes in the global economy, we make assumptions about economic and factor growth rates. Growth rates for 1992-2010 are adapted from Anderson et al. (1996) and Arndt et al. (1996). Growth rates for 2010-2020 are adapted from Bach (1997).¹¹ Indonesia has exhibited impressive economic growth since the mid 1960s and projected growth rates are relatively high during the period to 2020.¹² The average annual growth rates of 6.6 percent for 1992-2010 and 6.9 percent for 2010-2020 are broadly in line with other projections for Indonesia. They are a little lower than the BAPPENAS estimates presented in Anderson and Pangestu (1995), but higher than the ‘moderate growth path’ estimated by Duchin et al. (1993). A summary of the cumulative and annual assumptions with respect to growth in GDP and factors of production for all

¹¹ These growth rates are all based on World Bank projections. Existing projections from 1992-2005 are assumed to continue at a similar rate to 2010. A new set of projections is developed for the period 2010-2020; it is adapted from Bach’s (1997) projections for the period 1992-2020.

¹² It is assumed here that the current financial crisis will not affect long-term economic growth in the region.

regions is provided in Table 4.5(a) for 1992-2010. Table 4.5(b) summarises assumptions made for the period 2010-2020.

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 and Anderson 1997). Therefore, the assumption made here is that agricultural productivity increases at a rate of 0.7 percent per annum higher than other sectors.¹³

Given our factor productivity differential assumption, Table 4.6 shows the endogenously projected factor productivity growth where value added augmenting technical change differs for agricultural and other sectors of the economy. For Indonesia, based on the growth assumptions made, cumulative percentage increases in total factor productivity are projected to be 39.7 for agriculture and 26.3 for other sectors from 1992-2010. For 2010-2020, cumulative agricultural productivity growth is projected at 17.3 percent and other sectors at 10.1 percent.¹⁴

¹³ Alternative assumptions are possible. For instance, Bach (1996) argues that in the case of China, a 0.7 percent factor productivity differential is too high for agriculture. Bach instead assumes a constant two percent annual growth in agricultural productivity and allows only factor productivity in other sectors to endogenously accommodate the growth in GDP.

¹⁴ Total factor productivity rates are determined endogenously by the GDP and factor growth rates assumed. Negative numbers are therefore possible and Arndt et al. (1996) also report a small negative result for some regions.

The output response by each sector will be influenced by the type of growth shock applied. Table 4.7 shows the contribution to value added of each primary factor by sector for Indonesia. Since the greatest growth shocks applied to primary factors are to physical capital and skilled labour, we expect sectors using these factors intensively to do particularly well in our projections. The output response of sectors using land and specific natural resources are tied down much more. Indeed we use specific factors in precisely those sectors where it seems appropriate to tie down the supply response.

The implicit assumptions for price and income elasticities are also crucial determinants of the output response in GTAP, with the post-shock equilibrium reached depending critically on them (Hertel et al. 1997a). These elasticities drive the demand and supply responses in the model and are important determinants of projected changes of the economy, particularly where very large shocks are applied. Income elasticities are particularly important when modelling large income growth shocks. Fortunately GTAP has a relatively sophisticated representation of consumer demand. Non-homothetic preferences are captured through use of a constant difference of elasticities (CDE) function (Hertel and Tsigas 1997). This lies between the commonly used constant elasticities of substitution (CES) function and fully flexible functional forms. The advantage of this demand system is that non-homothetic demand can be calibrated to replicate a pre-specified vector of own-price and income elasticities of demand (Huff et al. 1997). The GTAP income elasticities for Indonesia are reported in the first column of Table 4.8.

Elasticities in a general equilibrium closure reflect full adjustment in all markets with all endogenous variables permitted to adjust to new equilibrium values.¹⁵ Prices and quantities of produced commodities are endogenously determined by households and firms optimising, subject to the resource limitations of the economy. Households satisfy their budget constraints and firms make zero pure profits. To generate a matrix of price elasticities of demand for all traded commodities, the output tax is shocked enough to raise the market price by 1 percent, one commodity and one region at a time (Pearson 1995, Hertel et al. 1997a). The general equilibrium price elasticity of demand of good i in region r with respect to good j in region s is defined as follows:

$$e_{(i,r),(j,s)} = qo_{(i,r)} / pm_{(j,s)}$$

where $qo_{(i,r)}$ is the proportional change in output of commodity i in region r and $pm_{(j,s)}$ is the proportional change in the market price of commodity j in region s . This gives an $(i,r)*(j,s)$ matrix of elasticities containing the own price elasticity of demand as well as the cross price intraregional and interregional elasticities.

Table 4.9 presents the intraregional elasticities for Indonesia for grains, processed foods, textiles and other private services. The own price elasticities of demand are all negative, as indicated by the negative results for $e_{(i,r),(i,r)}$. These own price elasticities are determined by a number of things including the mix of

final demand, private household's own price elasticity of demand and exposure to trade (Hertel et al. 1997a). For example, the own price elasticity of -10 for the textile, wearing apparel and leather sector is much stronger than the -0.9 for the processed food sector. The high elasticity is driven partly by the relatively high own price compensated elasticity of household demand of -0.18 for textiles compared to -0.10 for processed food (see Table 4.8). Also textiles have much better export opportunities as indicated in Table 4.10, where almost 50 percent of textile output is exported compared with under 7 percent of processed foods.

The intraregional cross-price elasticities tend to be positive, as shown by the sample sectors in Table 4.9, indicating that tradable commodity *i* is a general equilibrium substitute to tradable commodity *j*. An increased market price of one commodity induces substitution away from the commodity. Since we are operating in a general equilibrium framework, the resources released from *i* in *r* must be absorbed by other sectors in the region, and output in other sectors tends to increase. For example, if the output tax on textiles is raised enough to raise the market price by one percent demand, and therefore supply, will fall by 10 percent as indicated by the own price elasticity in Table 4.9. This releases resources which enables other sectors to expand. The expansion is fairly weak in the first 9 sectors that use land or a specific factor, neither of which are freed up by the textile sector. The notable exception is the coal sector which grows by 1.3 percent as a result of the 1 percent increase in the market price of textiles. This sector is able to respond with relative strength as it makes only a very small

¹⁵ See Hertel et al. (1997a) for more discussion of the differences between general and partial equilibrium elasticities.

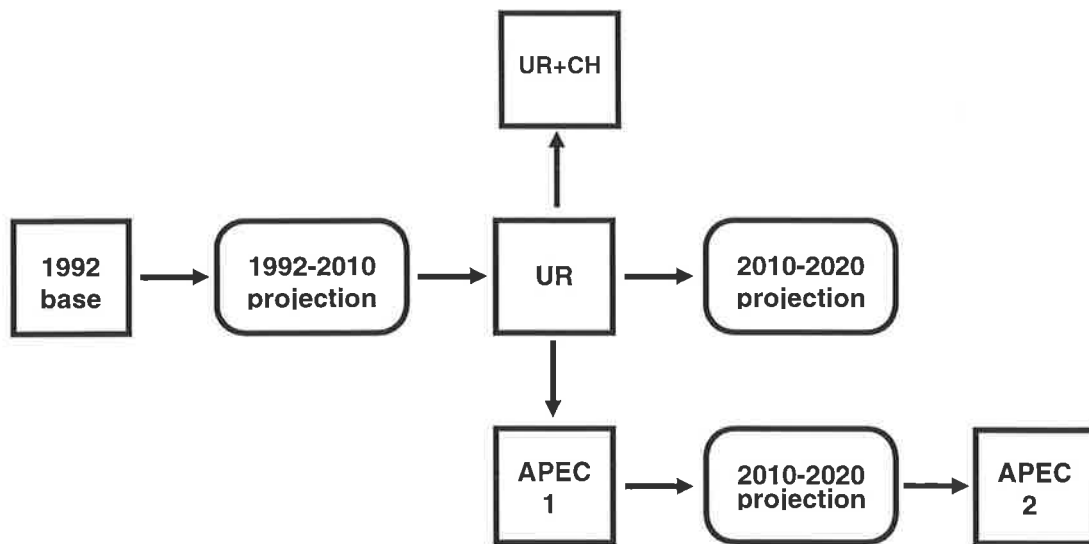
claim on economywide resources and it has significant export opportunities. Table 4.10 shows that the coal sector contributes only 0.36 percent to total output and 72 percent of its output is exported. This relatively small claim on economywide resources coupled with significant export opportunities tends to facilitate strong expansionary opportunities (Hertel et al. 1997a). For the opposite reasons, the proportionate responses of the various service industries are small since they tend to be relatively large sectors with limited export opportunities. For example the other private services sector is shown in Table 4.9 to have relatively small general equilibrium price responsiveness; it is a large sector (almost 16 percent of output) with very limited export opportunities.

Differences in the relative rates of factor accumulation interact with the various sectoral factor intensities and the elasticities to drive changes in sectoral composition of output over time.

4.3.2 Simulations

Simulations conducted are summarised in Figure 4.2. The base year for the GTAP V3 database is 1992, where protection vectors are at pre-Uruguay Round levels. Details of each structural growth and trade reform scenario follow.

Figure 4.2 *Summary of simulations*



1992-2010

Growth shocks from Table 4.5(a) are applied to GDP, unskilled labour, skilled labour, capital and the population level to simulate the cumulative change in them for 1992-2010. Total factor productivity is endogenously determined, though it is set to 0.7 percent per annum higher for agricultural sectors, as discussed in Section 4.3.1.

Uruguay Round liberalization

Uruguay Round liberalization is simulated from the updated 2010 database. Cuts to tariff rates, agricultural export subsidies and elimination of the Multifibre Arrangement (MFA) quotas are needed to generate a credible post-Uruguay Round environment from the GTAP protection data (McDougall 1996).

Version 3 of the GTAP database provides post-Uruguay Round protection vectors which draw heavily on the work of the World Bank (Reincke 1997; Ingco 1997). Tariff levels are exogenously shocked to achieve these post-Uruguay Round levels.¹⁶ MFA quotas which restrict textile, leather and wearing apparel exports from low-cost suppliers to the industrialised markets are represented as bilateral export tax equivalents in the exporting LDCs in the GTAP database (Gehlhar et al. 1997; Huff 1997). These LDC export taxes are reduced by the appropriate amount to simulate removal of MFA quotas.¹⁷

The appropriate reductions to agricultural export subsidies when modelling the Uruguay Round agreement are debatable. Since elimination proved politically impossible, the final binding agreement requires that developed countries reduce their spending on export subsidies by 36 percent or reduce the volume of subsidized exports by 21 percent over a six year period.¹⁸ Developing countries are required to reduce spending by 24 percent or quantity by 14 percent over a ten year period (FAO 1995, p. 253; Hathaway and Ingco 1995, p.19). Agricultural export subsidies are thus to be reduced only by fairly small amounts, so large quantities of subsidised exports will still be able to enter world markets. It is an untidy arrangement that is difficult to monitor, and it is impossible to say exactly how great will be the impact on volumes or prices

¹⁶ See Appendix C for pre- and post-Uruguay Round average tariff rates for Indonesia.

¹⁷ The starting point for this is quotas at their 1992 level. For modelling of the quota acceleration built into the Agreement on Textiles and Clothing, see Anderson et al. (1997). Anderson et al. (1997) also model import access commitments for rice in Korea, Japan and the Philippines by assuming that the ratio of rice imports to domestic rice consumption will go up to 8 percent.

¹⁸ Reductions were originally from average 1986-90 levels. However, in some cases, 1992 subsidies were well above these levels and the final agreement imposed the reduction of export subsidies from 1991-92 or 1986-90 levels, whichever was the higher (FAO 1995, p. 253).

(FAO 1995: 253-54). The assumption made here is that agricultural export subsidies are reduced by 36 percent in developed economies.

In the standard Uruguay Round simulation, China is assumed not to liberalize. The assumption is that China receives MFN status in most markets as reflected in the GTAP database post UR tariff vectors with the exception of MFN status on textiles and clothing. We follow the assumption of Anderson et al. (1997) that this would be perhaps too painful for OECD countries.

Uruguay Round liberalization with China included

This simulation is the same Uruguay Round liberalization discussed above, but with an additional assumption that China is fully integrated into the WTO by 2010. In this simulation, China reduces tariffs in accordance with the offer made by China to WTO member countries in late 1994 (Bach et al. 1996).¹⁹ These tariff reductions may be conservative as the offer was unacceptable to the WTO members at the time (Anderson et al. 1997). However the offer represents substantial reductions in protection rates by China. In addition to reducing tariffs, China is assumed to gain improved market access with the elimination of MFA quota restrictions.

¹⁹ Christian Bach kindly provided post-WTO membership rates for China for the full disaggregated GTAP database.

APEC 1

This simulation starts from the updated 2010 dataset which includes Uruguay Round trade liberalization. APEC Heads of Government agreed in November 1994 to eliminate, on a Most-Favoured-Nation (MFN) basis, all trade barriers in the APEC region by 2010 in the case of advanced countries and by 2020 in the case of developing countries (Anderson et al. 1997: 13). For this 2010 APEC simulation, an optimistic approach is taken. Full removal of tariffs on a MFN basis is assumed for the APEC high-income group by 2010. For Indonesia and other low-income APEC countries, it is assumed they will be 60 percent of the way towards their 2020 goal of full liberalization by 2010.²⁰

2010-2020

The starting point for this projection is the 2010 database including Uruguay Round implementation. Growth shocks from Table 4.5(b) are applied to GDP, unskilled labour, skilled labour, capital and the population level to simulate the cumulative change in these for 2010-2020. Total factor productivity is endogenously determined, though it is set to 0.7 percent per annum higher for agricultural sectors than for non-agricultural sectors. This simulation is repeated to acquire 2020 updated data that includes APEC 1 in addition to the Uruguay Round (this simulation uses the APEC 1 updated database as a starting point and imposes the same growth shocks as does the standard 2010-2020 projection).

²⁰ Indonesia's average tariff rates following APEC 1 are reported in Appendix C.

APEC 2

Starting from the 2020 APEC updated data, the remaining 40 percent of tariff reduction is simulated by APEC developing countries to achieve full liberalization on a MFN basis.

4.4 Structural change: 1992-2020

4.4.1 The changing structure of the global economy

The structural change projected for 1992-2010 and 2010-2020 has implications for the shape of the world economy as economies and factors grow at different rates. The structural change projections will also cause large relative shifts in production in the Indonesian economy. The period to 2020 is likely to see large changes in the global economy. Table 4.11 shows the changes in world output projected to 2010 and 2020.²¹ The size of the world economy is projected to increase by 65 percent between 1992 and 2010, then by a further 35 percent by 2020. This implies a global economy in 2020 which is 2.2 times as large as in 1992. Developing countries are set to gain enormously in significance, particularly the rapidly growing East Asian countries. Developing APEC economies are projected to more than double their contribution to world output, from 5.5 to 12.7 percent during the projected period 1992-2020. Indonesia is projected to almost treble its contribution to world output, from 0.55 to 1.53 percent during this period.

All regions are projected to experience large increases in trade as their incomes grow. Table 4.12 shows the projected change in exports and imports by region for 2010 and 2020. Indonesia and the other developing APEC economies increase their exports and imports by the largest proportion. Indeed to 2010, exports from and imports to the developing APEC region are projected to increase by well over 200 percent. This is over three times the average projected increase in exports and imports for other regions. With trade liberalization, these results are later shown to be even more striking.

4.4.2 The changing structure of the Indonesian economy

For Indonesia, trade with other developing countries will increase in relative importance. Imports will increasingly come from developing countries to Indonesia, with the share they provide rising from 20 percent of Indonesia's total imports in 1992 to 40 percent in 2020. High income countries continue to take the majority of Indonesia's exports. Table 4.13 details the changing profile of Indonesia's trading partners anticipated with the structural changes to 2010 and 2020.

The structure of production in Indonesia is expected to change significantly in coming decades. There has already been a large reduction in the importance of the agricultural sector (Anderson and Pangestu 1995) and this trend is set to

²¹ The base projection from 1992 to 2010 maintains initial protection data. Projections from 2010 to 2020 begin with the post-Uruguay Round updated 2010 database.

continue. Anderson and Pangestu (1997) present projected changes in the relative importance of each sector to GDP over the period 1992-2005. The trend they report, with Indonesia moving away from agricultural and other natural resource based sectors, is projected to continue to 2010 and 2020. Table 4.14 shows the simulated changing contribution to the composition of total output in Indonesia from 1992 to 2010 and 2020. The contribution of all agricultural and natural resource sectors falls for 1992-2010. This continues for 2010-2020. Sectors that increase their contribution to GDP include the textile sector, which experiences particularly strong growth and increases its contribution by the largest amount (74 percent in the eighteen years to 2010 and by a further 42 percent in the ten years to 2020). As discussed in Section 4.3.1, the textiles sector has relatively high own and cross price elasticities of demand which enables it to respond strongly to changed incentives in the economy such as the growth shocks. Other manufactures and services also experience relatively high growth in output, while agricultural and other primary sectors tend to increase output by a much smaller proportion.

4.5 Trade policy changes

4.5.1 Uruguay Round liberalization

Trade reform, such as implementation of the Uruguay Round agreement and APEC liberalization, offer important opportunities for the Indonesian and other economies in to the next century. We first discuss the results of Uruguay Round

liberalization with and without the inclusion of China. Then APEC liberalization is discussed in Section 4.5.2. Table 4.15 reports projected changes in the quantity of regional GDP and changes in welfare resulting from implementation of the Uruguay Round, without and with the inclusion of China. The first column indicates an increase in the quantity of real GDP for all regions, reflecting improved allocation of available resources with trade liberalization and also the response of each region to terms of trade effects. APEC developing regions, including Indonesia, experience the greatest proportional increases in output. Real GDP increases of 1.6 are projected for the APEC developing countries while Indonesia's GDP is projected to rise by 1.9 percent. Other regions do not do quite so well and are projected to experience smaller increases of approximately 0.3 percent with Uruguay Round implementation. When China is included in the liberalization, the change in real output for the developing APEC economies increases by an additional 1.2 percent. However, Indonesia's GDP gain now falls a little to 1.5 percent.

The second column of Table 4.15 shows the change in welfare for each region, as measured by an equivalent variation in income. The total world increase in welfare with Uruguay Round liberalization is projected to be US\$173 billion. With the inclusion of China in the agreement, this welfare increase is projected to increase by more than 25 percent to US\$218 billion. The inclusion of China clearly shifts a greater proportion of the gains into the developing APEC region. All regions are projected to experience increased welfare with Uruguay Round liberalization, but these gains are not evenly spread. To assist understanding of these results, welfare changes are decomposed. The final three columns of Table

4.15 break the increase in welfare down into three components: allocative efficiency effects, terms of trade effects and marginal utility of income effects, following Huff and Hertel (1996) and McDougall (1993).

Allocative efficiency gains result when resources are reallocated into areas of more efficient production. These are positive for all regions with Uruguay Round liberalization. Terms of trade effects are negative for some regions. Indonesia, Other developing APEC economies, and the Rest of the World economies are projected to experience negative terms of trade effects. These adverse terms of trade effects are, however, swamped by the improved allocative efficiency for all of these regions. The final contribution to welfare effects comes from the change in the marginal utility of income term effect reported in the last column of Table 4.15. This reflects non-homothetic household preferences. When policy shocks increase household utility, the proportion of income spent on inferior goods reduces, leaving more income available for all other goods and a positive effect on welfare (Huff and Hertel 1996). These marginal utility of income effects are therefore driven largely by the parameters of the CDE household preference function.

Table 4.16 shows the anticipated proportional changes in exports and imports with Uruguay Round implementation. Uruguay Round liberalization is expected to lead to increased imports and exports for all regions in our aggregation. Indonesia experiences a 21 percent increase in imports and a 24 percent increase in exports with Uruguay Round implementation. These figures are a little lower (14 and 18 percent) when liberalization by China is included. For other more



aggregated regions, the increases in trade tend to be lower for the base Uruguay Round simulation. Increases in imports and exports of around five to ten percent are anticipated when China does not liberalize. With the inclusion of China in Uruguay Round implementation, the developing APEC region in particular experiences a much greater increase in trade. Both exports and imports increase by well over 20 percent. This is partly at the expense of Indonesia, which loses some of its anticipated increase in trade when China moves into the WTO.

4.5.2 APEC liberalization

Table 4.17 indicates the projected changes in the quantity of regional GDP and economic welfare with the implementation of stages 1 and 2 of APEC liberalization. As with Uruguay Round liberalization, all regions experience some increase in output. APEC developing regions experience the greatest increases in output. For the developing APEC regions, the first stage of tariff liberalization to 2010 results in a projected 2.1 percent boost to output. Implementation of the second stage contributes a further 0.8 percent to real GDP.²²

The second column of Table 4.17 shows the projected change in welfare in US\$m. Total world welfare gains from APEC liberalization are in the order of US\$209 billion for the first phase and US\$60 billion for the second stage.²³

²² However if agriculture is not included, these gains lower to around 1.2 and 0.5 percent respectively (unreported simulation).

²³ If agricultural markets are not reformed, these gains lower by over 25 percent (unreported simulation).

Allocative efficiency gains are positive for all regions and all simulations. Adverse terms of trade effects may give rise to the sometimes unexpected signs on welfare effects following trade liberalization, even when a region experiences an increase in real output and improved allocative efficiency. For example, Indonesia experiences a large deterioration in terms of trade with all of the APEC liberalization scenarios simulated. This deterioration in the terms of trade is sufficiently strong that a net welfare loss is shown, even though allocative efficiency improves and GDP increases.

APEC liberalization leads to significantly increased imports and exports, particularly for the APEC economies themselves. Table 4.18 shows the proportional changes in exports and imports for the two stages of APEC liberalization. The high income APEC regions show particularly large increases in trade for APEC 1 since this is where they do all of their trade reform. Imports and exports increase by around 25 percent. For Indonesia and other developing APEC regions, the first stage of APEC liberalization leads to significant increases in trade of approximately 20 percent, while smaller but still substantial increases in trade flows result from the second stage of APEC trade reform.

4.6 Conclusions

Large changes are projected for the structure of the global economy between 1992 and 2020. World output is projected to more than double. Simulation results suggest that developing APEC regions will increase their contribution to

world output by 130 percent during the period 1992-2020, while the contribution of Indonesia to global output almost trebles.²⁴ The relative importance of the agricultural sector in Indonesia has declined in recent decades and this decline is projected to continue. Manufacturing and services increase in importance as the composition of output in Indonesia progressively moves away from agricultural and natural resource sectors. International trading patterns also change. Both imports and exports are projected to increase significantly with Indonesia's economic growth, and developing countries become increasingly important trading partners to Indonesia.

Trade reform, particularly multilateral trade liberalization, further enhance Indonesia's economic growth and development prospects. Uruguay Round implementation is projected to lead to a 1.9 percent increase in real GDP (a little lower if China is included). APEC liberalization is projected to give rise to an increase in real GDP of almost 1 percent for the first stage where developed economies fully liberalize. There is a further 0.3 percent increase in GDP projected for the second stage, where developing economies complete their liberalization (the gains are lower if agricultural trade is not liberalized).

The structural change and the implementation of trade agreements discussed here have important implications for the level of pollution in Indonesia. Chapter Five analyses the effects on water and air pollution of the changes in the aggregate level of output, the composition of that output, and the technology used to produce it.

²⁴ The adverse effects of the current financial crisis in Indonesia and other East Asian economies are not included here.

Table 4.1: Regional aggregation

<i>Regional Aggregation</i>	<i>Abbreviation</i>	<i>GTAP Aggregation</i>
Indonesia	IND	Indonesia
Other developing APEC economies	OAD	China Korea Thailand Malaysia Philippines Mexico Chile
High income APEC economies	HIA	Australia New Zealand United States Canada Japan Hong Kong Singapore Taiwan
High income European economies	HIE	European Union-12 EU-3 (Austria, Finland and Sweden) EFTA (Iceland, Norway, Switzerland)
Rest of the world's developing and transition economies	ROW	Argentina Brazil Rest of South America Central America and the Caribbean India Rest of South Asia (Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka) Middle East and North Africa Sub Saharan Africa Central European Associates (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) Former Soviet Union Rest of World

Table 4.2: Commodity aggregation

<i>Aggregated Commodity</i>	<i>Abbreviation</i>	<i>GTAP Commodity</i>
Paddy Rice	PDR	Paddy rice
Coarse grains	GRA	Wheat Coarse grains
Non-grain crops	NGC	Non grain crops
Livestock	LVS	Wool Other livestock
Forestry	FOR	Forestry
Fisheries	FSH	Fisheries
Coal	COL	Coal
Oil	OIL	Oil
Gas	GAS	Gas
Other minerals	OMN	Other minerals
Food processing	PRF	Processed rice Meat products Milk products Other food products Beverages and tobacco
Textiles	TEX	Textiles Wearing apparels Leather etc.
Wood products	LUM	Lumber
Paper	PPP	Pulp paper etc.
Petroleum and coal	PTC	Petroleum and coal
Chemicals, rubber and plastics	CRP	Chemicals rubbers and plastics
Nonmetallic minerals	NMM	Nonmetallic minerals
Other manufactured products	OMF	Primary ferrous metals Nonferrous metals Fabricated metal products Transport industries Machinery and equipment Other manufacturing
Electricity, water and gas	EGW	Electricity water and gas
Construction	CNS	Construction
Trade and transport	TRT	Trade and transport
Other services: private	OSP	Other services (private)
Other services: government	OSG	Ownership of dwellings Other services (govt.)

Table 4.3: Distribution of factor payments in Indonesia within sectors: percentage of total factor payments, 1992

<i>Sector</i>	<i>Unskilled labour</i>	<i>Skilled labour</i>	<i>Physical capital</i>	<i>Land</i>	<i>Specific natural resource</i>
PDR	0.42	0.10	0.16	0.32	
GRA	0.40	0.13	0.24	0.23	
NGC	0.41	0.13	0.22	0.24	
LVS	0.40	0.15	0.23	0.22	
FOR	0.32	0.09	0.24	0.18	0.18
FSH	0.35	0.11	0.22		0.33
COL	0.49	0.14	0.15		0.23
OIL	0.10	0.05	0.34		0.51
GAS	0.08	0.10	0.33		0.49
OMN	0.37	0.14	0.20		0.30
PRF	0.35	0.12	0.53		
TEX	0.48	0.11	0.41		
LUM	0.49	0.14	0.37		
PPP	0.41	0.20	0.39		
PTC	0.22	0.11	0.67		
CRP	0.32	0.19	0.49		
NMM	0.41	0.15	0.44		
OMF	0.42	0.22	0.36		
EGW	0.20	0.14	0.67		
CNS	0.48	0.18	0.35		
TRT	0.44	0.16	0.40		
OSP	0.20	0.21	0.59		
OSG	0.43	0.48	0.10		

Source: Modified GTAP model.

Table 4.4: Summary of factor payments in 5 region aggregation, US\$m, 1992 [%]

	<i>IND</i>	<i>OAD</i>	<i>HIA</i>	<i>HIE</i>	<i>ROW</i>
Unskilled labour	27,959 [23.6]	333,980 [31.2]	3,725,068 [37.4]	2,599,440 [34.6]	935,841 [33.8]
Skilled labour	10,209 [8.6]	118,034 [11.0]	2,415,091 [24.2]	1,741,261 [23.2]	399,462 [14.4]
Physical capital	59,908 [50.5]	526,401 [49.2]	3,708,972 [37.2]	3,041,087 [40.4]	1,228,305 [44.3]
Land	11,091 [9.4]	64,032 [6.0]	57,999 [0.6]	32,616 [0.4]	81,225 [2.9]
Specific natural resource	9,384 [7.9]	27,209 [2.5]	62,498 [0.6]	107,223 [1.4]	125,643 [4.5]

Source: Modified GTAP model.

Table 4.5: Assumptions made in the projections: cumulative [annual] percentage changes in GDP and factor endowments

(a) 1992-2010

<i>Region</i>	<i>Real GDP</i>	<i>Physical capital</i>	<i>Unskilled labour</i>	<i>Skilled labour</i>	<i>Population</i>
IND	215 [6.6]	260 [7.4]	44 [2.0]	449 [9.9]	27 [1.4]
OAD	202 [6.3]	312 [8.2]	26 [1.3]	167 [5.6]	19 [1.0]
HIA	66 [2.9]	101 [4.0]	16 [0.8]	150 [5.2]	16 [0.8]
HIE	55 [2.5]	53 [2.4]	1 [0.1]	394 [9.3]	3 [0.2]
ROW	73 [3.1]	61 [2.7]	43 [2.0]	151 [5.3]	40 [1.9]

(b) 2010-2020

<i>Region</i>	<i>Real GDP</i>	<i>Physical capital</i>	<i>Unskilled labour</i>	<i>Skilled labour</i>	<i>Population</i>
IND	95 [6.9]	135 [8.9]	17 [1.6]	77 [5.9]	14 [1.3]
OAD	72 [5.6]	88 [6.5]	9 [0.9]	51 [4.2]	9 [0.8]
HIA	27 [2.5]	47 [3.9]	3 [0.3]	53 [4.3]	7 [0.7]
HIE	28 [2.5]	34 [3.0]	-4 [-0.4]	79 [6.0]	0 [0.0]
ROW	49 [4.1]	46 [3.9]	29 [2.6]	62 [5.0]	18 [1.7]

Source: Author's calculations from Anderson et al. (1996), Arndt (1996) and Bach (1997).

Table 4.6: Projected total factor productivity changes

	<i>1992-2010</i>		<i>2010-2020</i>	
	<i>Agricultural sectors</i>	<i>Other sectors</i>	<i>Agricultural sectors</i>	<i>Other sectors</i>
IND	39.7	26.3	17.3	10.1
OAD	35.4	22.0	25.3	18.1
HIA	10.4	-3.0	4.6	-2.6
HIE	21.4	8.0	13	5.8
ROW	24.5	11.1	16.4	9.2

Source: Authors' model results.

Table 4.7: Contribution to value added by each primary factor in Indonesia (%)

	LAND	UNSKLAB	SKLAB	CAPITAL	NATRES
PDR	51	37	5	7	
GRA	51	37	5	7	
NGC	51	37	5	7	
LVS	51	38	4	7	
FOR	25	14	2	34	25
FSH		14	2	34	50
COL		46	6	19	29
OIL		2	0	39	59
GAS		2	0	39	58
OMN		26	4	28	41
PRF		23	5	72	
TEX		26	5	69	
LUM		23	3	73	
PPP		28	6	66	
PTC		18	5	77	
CRP		23	6	71	
NMM		19	4	78	
OMF		27	6	68	
EGW		17	9	74	
CNS		47	8	45	
TRT		15	4	81	
OSP		18	10	72	
OSG		34	54	12	

Source: Modified GTAP model.

Table 4.8: Income elasticities and own price compensated elasticities of household demand for Indonesia

<i>Sector</i>	<i>Income elasticity</i>	<i>Own price compensated elasticity</i>
PDR	0.45	-0.09
GRA	0.09	-0.02
NGC	0.64	-0.12
LVS	0.77	-0.16
FOR	1.42	-0.29
FSH	1.42	-0.28
COL	1.42	-0.29
OIL	1.42	-0.29
GAS	1.42	-0.29
OMN	1.42	-0.29
PRF	0.48	-0.10
TEX	0.91	-0.18
LUM	1.42	-0.29
PPP	1.42	-0.29
PTC	1.42	-0.29
CRP	1.42	-0.28
NMM	1.42	-0.29
OMF	1.14	-0.23
EGW	1.05	-0.21
CNS	1.05	-0.22
TRT	1.39	-0.21
OSP	1.25	-0.19
OSG	1.05	-0.21

Source: Version 3 of GTAP.

Table 4.9: General equilibrium cross-price elasticities of demand for selected Indonesian sectors

	GRA	PRF	TEX	OSP
PDR	0.00	-0.92	0.23	0.06
GRA	-1.04	0.04	0.26	0.05
NGC	0.03	0.29	0.29	0.07
LVS	0.01	-0.36	0.17	0.07
FOR	0.01	0.25	1.13	0.11
FSH	0.00	0.02	0.38	0.10
COL	0.01	0.26	1.30	0.10
OIL	0.00	0.06	0.56	0.15
GAS	0.00	0.06	0.56	0.16
OMN	0.01	0.14	0.85	0.17
PRF	0.00	-0.93	0.23	0.06
TEX	0.02	0.38	-10.03	0.59
LUM	0.02	0.33	1.62	0.15
PPP	0.01	0.08	0.94	-0.02
PTC	0.00	0.08	0.09	0.02
CRP	0.00	0.18	0.42	0.11
NMM	0.00	0.14	1.06	0.05
OMF	0.01	0.31	2.20	0.26
EGW	0.00	0.06	-0.20	0.02
CNS	0.00	0.01	0.02	-0.02
TRT	0.00	0.01	0.40	0.12
OSP	0.00	0.05	0.27	-0.61
OSG	0.01	0.16	0.17	0.22

Source: Authors' model results.

Table 4.10: Share in total output and export share by sector for Indonesia, 1992 (%)

	Sectoral output/total output	Exports/output by sector
PDR	3.33	0.00
GRA	0.36	2.32
NGC	5.45	16.87
LVS	1.42	2.61
FOR	1.12	1.49
FSH	1.68	29.43
COL	0.36	71.76
OIL	3.25	72.54
GAS	2.69	66.24
OMN	1.35	33.91
PRF	10.56	6.61
TEX	6.21	48.50
LUM	3.18	65.71
PPP	1.20	16.75
PTC	2.35	6.95
CRP	4.13	21.99
NMM	0.82	18.23
OMF	8.82	16.14
EGW	1.22	0.00
CNS	9.74	0.00
TRT	11.02	6.17
OSP	15.96	2.58
OSG	3.78	0.07

Source: Authors' model results.

Table 4.11: Changing structure of global GDP, 1992, 2010 and 2020

	<i>1992</i>		<i>2010</i>		<i>2020</i>	
	<i>GDP</i> <i>(US\$b)</i>	<i>% of world</i> <i>GDP</i>	<i>GDP</i> <i>(US\$b)</i>	<i>% of world</i> <i>GDP</i>	<i>GDP</i> <i>(US\$b)</i>	<i>% of world</i> <i>GDP</i>
IND	128	0.55	392	1.02	788	1.53
OAP	1291	5.54	3859	10.07	6555	12.70
HIA	10828	46.47	17350	45.25	21940	42.52
HIE	7950	34.12	11563	30.16	14713	28.51
ROW	3103	13.32	5176	13.50	7608	14.74
TOTAL	23301	100	38340	100	51604	100

Source: Authors' model results.

Table 4.12: Growth in the volume of imports and exports by region, 1992, 2010 and 2020 [%]

	<i>1992-2020</i>		<i>2010-2020</i>	
	<i>Imports</i>	<i>Exports</i>	<i>Imports</i>	<i>Exports</i>
IND	216	177	119	127
OAP	230	269	80	93
HIA	79	77	40	37
HIE	63	62	38	34
ROW	72	65	48	46

Source: Authors' model results.

Table 4.13: Changing share of Indonesia's trade with other regions, 1992, 2010 and 2020 (%)

	<i>OAD</i>	<i>HIA</i>	<i>HIE</i>	<i>ROW</i>
1992				
Exports	14	61	18	8
Imports	12	49	31	8
2010				
Exports	18	49	23	10
Imports	20	44	25	10
2020				
Exports	13	34	46	7
Imports	28	39	22	12

Source: Authors' model results.

Table 4.14: Aggregate cumulative percentage change in the compositional share of total GDP output in Indonesia, 1992-2010 and 2010-2020 [%]

<i>Sector</i>	<i>1992-2010</i>	<i>2010-2020</i>
PDR	-41	-31
GRA	-61	-48
NGC	-50	-41
LVS	-32	-30
FOR	-36	-26
FSH	-41	-37
COL	-29	-23
OIL	-32	-16
GAS	-36	-18
OMN	-27	-7
PRF	-41	-31
TEX	74	42
LUM	-45	-32
PPP	37	19
PTC	12	13
CRP	21	13
NMM	17	16
OMF	51	55
EGW	17	12
CNS	8	16
TRT	28	13
OSP	25	10
OSG	74	-18

Source: Authors' model results.

Table 4.15: Welfare effects of Uruguay Round trade liberalization, 2010

	<i>Change in the quantity of GDP (%)</i>	<i>Change in Welfare (US\$m)</i>	<i>Allocative efficiency (US\$m)</i>	<i>Terms of trade (US\$m)</i>	<i>MU of income (US\$m)</i>
Uruguay Round without China included					
IND	1.86	6012	7268	-1012	-244
OAD	1.63	46449	62705	-13914	-2342
HIA	0.32	67697	55117	13511	-932
HIE	0.31	40646	35771	5835	-960
ROW	0.32	12029	16664	-4463	-172
... with China included					
IND	1.49	2531	5446	-2821	-95
OAD	2.81	66379	107758	-38456	-2924
HIA	0.34	87699	58454	30389	-1144
HIE	0.34	54280	38920	16630	-1270
ROW	0.26	7502	13507	-5896	-110

Source: Authors' model results.

Table 4.16: Changes in volume of imports and exports with Uruguay Round liberalization, 2010 (%)

	<i>Uruguay Round</i>		<i>UR with China</i>	
	<i>Imports</i>	<i>Exports</i>	<i>Imports</i>	<i>Exports</i>
IND	21.2	24.0	14.3	18.1
OAD	9.8	10.8	22.2	25.3
HIA	7.9	7.4	9.9	8.8
HIE	5.3	4.7	7.0	5.8
ROW	6.0	6.8	4.8	5.7

Source: Authors' model results.

Table 4.17: Welfare effects of APEC trade liberalization, 2010 and 2020

	<i>Change in the quantity of GDP (%)</i>	<i>Change in welfare (US\$m)</i>	<i>Allocative efficiency effects (US\$m)</i>	<i>Terms of trade effects (US\$m)</i>	<i>MU of income effects (US\$m)</i>
APEC 1, 2010					
IND	0.84	-1440	3354	-4660	-135
OAD	2.11	33009	81401	-45719	-2673
HIA	0.65	113569	113040	2969	-2441
HIE	0.08	45102	9859	35933	-690
ROW	0.16	18929	8420	10823	-315
APEC 2, 2020					
IND	0.27	-8320	1989	-10455	145
OAD	0.80	-23529	51974	-73833	-1671
HIA	0.00	42223	659	42263	-699
HIE	0.02	34421	2258	33009	-846
ROW	0.09	14519	6763	8260	-504

Source: Authors' model results.

Table 4.18: Changes in volume of imports and exports with APEC liberalization, 2010 and 2020 (%)

	<i>APEC 1, 2010</i>		<i>APEC 2, 2020</i>	
	<i>Imports</i>	<i>Exports</i>	<i>Imports</i>	<i>Exports</i>
IND	18.1	19.6	12.4	14.5
OAD	23.5	25.9	15.1	16.8
HIA	33.9	33.1	1.7	1.1
HIE	4.1	2.9	2.3	1.4
ROW	1.9	1.3	0.7	0.32

Source: Authors' model results.

5. AIR AND WATER POLLUTION IN INDONESIA TO 2020¹

5.1 Introduction

Environmental degradation can affect welfare. Hence the impact of structural and economic policy changes on the natural environment should be analysed along with the standard welfare effects discussed in the previous chapter (Anderson and Strutt 1996). With policy reform and growth there are changes in the scale of output, tastes, relative sector size and production technology. These can all affect the level of air and water pollution in Indonesia. We model these interacting forces and decompose the projected changes in environmental degradation to determine how they drive environmental change. We also compare the environmental effects of economic growth with those of trade liberalization.

The projections of structural change and trade liberalization presented in Chapter Four provide a starting point. We develop environmental side modules to analyse the implications of these changes for environmental degradation. The side modules are based on a comprehensive data set prepared for an environmental input-output model developed by Duchin et al. (1993) for

¹ This chapter formed the basis of a joint paper with Kym Anderson (Strutt and Anderson 1998).

Indonesia to the year 2020. The side modules run in tandem with GTAP. They are driven by the projected intersectoral movement of resources and changes in output, under the various scenarios.

Existing studies of the environmental impacts of growth and trade reform in developing countries tend to use US-based pollution data (based on Hettige et al. 1994).² They often present only a small range of pollution estimates or use very simple underlying economic models. This work contributes to the existing literature by using a very carefully specified global trade model along with Indonesia-specific estimates for a variety of pollutants across most sectors of the economy.³

5.2 Environmental side modules

We use side modules to project environmental outcomes in Indonesia for water use, water pollution and air pollution. They provide insights into the direction and magnitude of environmental change and can decompose the key forces driving this change. The approach of augmenting CGE models with environmental side models has been taken by a number of other researchers. For example, Bandara and Coxhead (1995) look at soil erosion in a single country

² Though some studies such as Begnin et al. (1996, 1997 and 1998) use input based pollution measures and Cole et al. (1997) adjust for regional differences in total pollution intensity using an environmental Kuznets curve approach.

³ This approach contrasts with that of Lee and Roland-Holst (1997), who use the IPPS of the World Bank (see Chapter 1 and Hettige et al. 1994) and are forced to apply US manufacturing sector emission intensities to Indonesia. As they note, this database is limited to industrial pollution (agriculture and services are omitted) and US technology and environmental standards may be quite different from those in Indonesia.

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 and Beghin et al. 1996). This is theoretically very appealing since it enables more direct analysis of environmental policies and environmental feedback effects. However, data and parameters are typically scarce.

Duchin et al. (1993) provide estimates of various types of environmental degradation across 30 sectors for 1985 and 2020. Where possible, the database is built using data collected in Indonesia. Those 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 trends.⁴ Specialists such as chemical engineers, hydrologists, environmental scientists, energy experts and agricultural scientists were consulted on the technologies likely to be adopted over the next several decades.

In their environmental data, Duchin et al. (1993) include water use, water pollution and air pollution. For water, there are data on the volumes of water used and discharged by sector. Four measures of the pollution content of the effluent are provided: biological oxygen demand (BOD),⁵ chemical oxygen demand (COD), dissolved solids, and suspended solids. The available air

⁴ 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.

pollutant indicators are carbon dioxide and oxides of sulphur and nitrogen which can cause local damage to health and property. Carbon dioxide is important also because of its potential contribution to global climate change.

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 2020.⁶ The GTAP 1992 benchmark database for Indonesia is then calibrated to this matrix of total emissions to derive environmental damage coefficients per unit of GTAP sectoral output. We derive projections of changes in the environmental coefficients to 2010 and 2020 from Duchin et al. (1993). The proportional changes in these environmental coefficients are then multiplied by the GTAP 1992 environmental coefficients to obtain GTAP environmental coefficients for 2010 and 2020.⁷

This approach captures the expected change in environmental coefficients in a consistent way that can be used to augment GTAP analysis. Each coefficient measures the estimated environmental impact per unit of economic activity, and how this changes over time.⁸

⁵ Which measures the weight of oxygen needed to degrade and stabilize biodegradable waste materials contained in the discharge.

⁶ Changes in environmental parameters per unit of output are assumed linear over the time period 1985-2020.

⁷ Environmental coefficients for Indonesia for 1992, 2010 and 2020 are provided in Appendix D.

⁸ However it may be that the technological projections developed “may be too conservative ... many projections were based on the opinions of experts who tended to focus on the period to 2005 and not much beyond” (Duchin et al. 1993, p. 43).

5.3 Decomposition of environmental effects

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.⁹ Define the total change in pollution (P) as the sum of the changes in pollution in each sector (P_j):

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

The change in pollution in each sector j is the sum of the “aggregate activity” effect (A_j^o), the “intersectoral composition” effect (C_j^o), and the “technology” effect (T_j):

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

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 (X_j). 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

⁹ 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.

the scale of output in each sector is then multiplied by the initial environmental coefficient for each sector (E_j^o) 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

$$C_j^0 = X_j * (x_j - g) * E_j^0$$

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. This “technology” effect has some similarities with the “technique” effect defined by Copeland and Taylor (1994). Changes in technology will change the amount of degradation caused by each unit of output in each sector.¹⁰ 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 (E_j^n) 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. The total technology effect, T_j , is thus as follows:

$$T_j = \left[(A_j^n - A_j^0) + (C_j^n - C_j^0) \right] + \left[X_j * (E_j^n - E_j^0) \right]$$

where

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

and

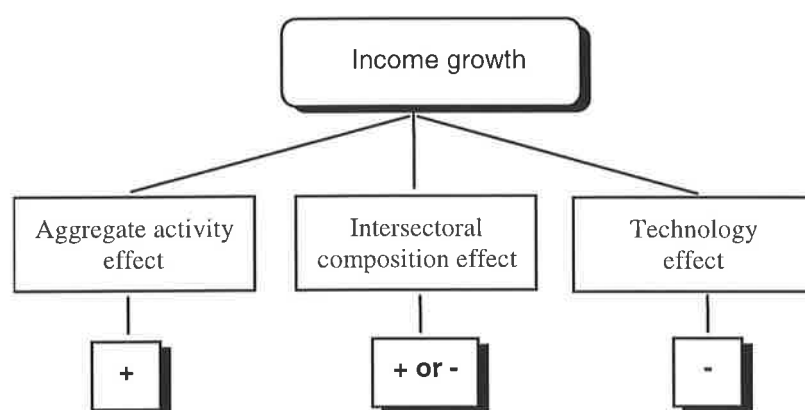
¹⁰ Higher incomes leading to more stringent environmental policies would add to this effect and are these are central to the “technique effect” (Copeland and Taylor 1994, Dean 1996). We do not explicitly include this possibility in the current analysis, though it would be a valuable further extension of this work.

$$C_j'' = X_j * (x_j - g) * E_j''$$

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.

Figure 5.1 summarises the anticipated sign of the three effects when there is income growth. With both structural change and trade liberalization, there are changes in the aggregate level of economic activity and in the composition of output. Technology also will change, though we assume here that the trade reform itself does not directly cause changes in technology.¹¹ Changes in aggregate output lead to changes in environmental degradation, given existing technology and the existing composition of output. For both structural change and trade liberalization, the aggregate activity effect will generally increase environmental damage. Intersectoral composition effects may be positive or negative, depending on whether output is increased or reduced in the most polluting sectors relative to other sectors. (In the long run, however, we generally expect economic growth to shift production into the more environmentally benign service sectors as incomes grow.) The technology effect tends to cause a reduction in emissions over time with a movement towards cleaner production methods. However we assume that there is no technology effect due to trade liberalization.

Figure 5.1 *Anticipated effect on emissions of income growth*



5.4 Projected environmental impacts of growth and structural changes for the periods 1992-2010 and 2010-2020

5.4.1 Output changes, 1992-2010 and 2010-2020

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

Table 5.1 shows the initial 1992 output level for each sector, evaluated at initial market prices, and the proportional changes in output by 2010 and 2020 due to economic growth and structural change, assuming no changes in trade policies globally. With the large growth in income projected from 1992 to 2010 and 2010 to 2020, all sectors exhibit increased output levels in Indonesia.

¹¹ We could model improved environmental policies accompanying increased trade. This would give rise to those changes directly affecting the production methods in use.

Particularly strong growth of 450 percent to 2010 and then a further 177 percent between 2010 and 2020, is projected for the textile sector. Other manufactured goods and service sectors also experience relatively strong growth in output, while agriculture and other primary sectors tend to increase output by a much smaller proportion. These results are driven by the factor and income growth shocks and the implicit income and price elasticities assumed for Indonesia and the other countries of the world (see Chapter Four, Tables 4.8 and 4.9).

Given these changes in output, we use environmental side modules to analyse the implications of these changes in output for air and water pollution.

5.4.2 Air pollution

Atmospheric emission changes are estimated for carbon dioxide and oxides of sulphur and nitrogen. Table 5.2 lists the initial 1992 level and projected base case (baseline) levels of emissions for 2010 and 2020. Large increases are projected for all of these air pollutants. Since the Indonesian economy is projected to grow by 215 percent between 1992 and 2010 and a by further 95 percent by 2020, it is not surprising that we find such large increases in projected emissions. Carbon emissions increase by 134 percent in the first projected period and by 56 percent for the decade to 2020. Sulphur oxides increase by 132 and 50 percent and nitrogen oxides increase by 162 and 65 percent.

The aggregate output effect increases air pollution, but the technology and intersectoral composition effects can dampen the impact of this increased aggregate output level on emissions. Tables 5.4(a) and 5.4(b) decompose 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 in these simulations, but that the intersectoral composition effects of structural change add to that effect for all air pollutants. This is because there is a relatively large 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, as shown in Table 5.1.

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 Tables 5.4(a) and 5.4(b), reflecting the improved technologies expected to become available.

5.4.3 Water use and pollution

Table 5.3 presents water use and water pollution results calculated for the various sectors using GTAP simulation results and a water use and pollution

side module. Increases in household water use are taken directly from estimates in Duchin et al. (1993).¹² 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 sectors more than double their water use, while household water use also increases by almost 50 percent. However increases in water use are dwarfed by the savings in water uptake that comes from the significantly improved efficiencies anticipated in irrigation delivery systems for paddy rice (Duchin et al 1993), which is the largest user of water in our model. In addition, the intersectoral composition effect causes reduced water withdrawals with the relative decline of the paddy rice sector. As a consequence of these two effects, over the projected periods total water withdrawals fall by 4 percent to 2010 and by a further 36 percent by 2020.

Between 1992 and 2010, we project water discharge to increase by 126 percent, with a further 29 percent increase by 2020 (Table 5.3). The decomposition in Tables 5.4(a) and 5.4(b) shows that the composition effect augments the aggregate activity effect a little. The relative increases are in textiles and clothing, pulp and paper and other manufactures, which are all large producers

¹² Household water use is exogenous with an assumed population increase to 263 million by 2020 (this is based on Duchin et al. (1993) estimate. The population based on a 1992 population of 189 million (FAO database) and our estimated growth rates to 2020 (Chapter 4, Table 4.5), is a little higher at 273 million.

of waste water. However improved technologies dampen the effect increase 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 scale effect, emissions of all water pollutants except for dissolved solids rise between 1992 and 2010 (see Table 5.4(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, etc. 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 percent 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.

5.5 Projected environmental impacts of Uruguay Round and APEC liberalization

5.5.1 Output changes due to trade reform

This section uses the side modules to analyse how much difference it will make to environmental effects when trade reform occurs in addition to structural growth. In particular we examine the projected environmental impacts of Uruguay Round implementation and the two stages of APEC trade reform.

The first two columns of Table 5.5 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 final two columns show the projected sectoral changes in output for the first and second stages of APEC liberalization. Some sectors reduce and other sectors increase their output level. This contrasts markedly with the results in Table 5.1 for structural change projections where all sectors increased their output. We therefore expect the composition effects to be much stronger here relative to the aggregate activity effects, which tend to dwarf all other effects with the massive income growth in the structural projections.

The results in Table 5.5 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 percent boost to output if China is kept out of the WTO or just under 40 percent if China is able to join

and gain improved access to textile and wearing apparel markets at Indonesia's expense. With APEC liberalization, the effects on the textile sector are much less pronounced as MFA quotas have already been phased out as part of the Uruguay Round's implementation. The sectors that tend to do well with the APEC reform are instead the coal and lumber sectors and non-metallic minerals.¹³ The coarse grain sector is also projected to do well.

5.5.2 Air pollution

We now use our environmental side modules to consider the implications of the various trade liberalization scenarios for air pollution in Indonesia. Emissions are expected to increase in some sectors and fall in others with Uruguay Round and APEC trade reform.

Table 5.6 indicates that a reduction in air pollution is projected under Uruguay Round liberalization (including China), rather than the increase feared by environmentalists. The reduction from 2010 baseline levels is 0.6 percent for carbon and sulphur oxides and 1.0 percent for nitrogen oxides. The decomposition in Table 5.11 shows the total change in emissions by sector to identify the sectors that are driving this reduction in air pollution. From the first three columns of Table 5.11, we find that the most significant reduction is contributed by the trade and transport sector. Other sectors such as the oil sector also significantly reduce air pollution as their output falls. The output of textiles

¹³ These are sectors which Indonesia's own policies tend to discriminate against (Strutt and Anderson 1998).

risers 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, the reductions in Indonesia's air pollution almost double relative to the reductions shown in Table 5.6.¹⁴ This is primarily because Indonesia's textile and clothing sector does not grow as much when China is included, therefore the textile and clothing sector does not pull resources away from other more polluting sectors to the same extent. For example, output in the trade and transport sector is reduced by only 1.3 percent compared with the 2.4 percent reduction without the inclusion of China in the Uruguay Round.

With additional APEC liberalization, air pollution is projected to increase as shown in Tables 5.7 and 5.8. However the increases are relatively small. For the first stage of APEC liberalization, the increases are approximately 1.0, 1.3, and 1.6 percent respectively from 2010 levels for carbon, sulphur and nitrogen emissions. For the second stage of APEC liberalization, these emissions increase from their 2020 levels by 0.8, 1.7 and 1.3 respectively. The net increase in air pollution, implies that the aggregate output effect outweighs any intersectoral composition and technology effects. While the increases in aggregate activity are lower than those projected for the Uruguay Round, APEC liberalization does not give rise to such strong intersectoral effects. (The textile industry does not draw so many resources from other more polluting sectors.) Note also that a small number of sectors can drive the results. For example, for

¹⁴ Unreported further results.

the first stage of APEC liberalization the trade and transport sector contributes over 68 percent of the increase in carbon, 52 percent of the increase in sulphur and 96 percent of the increase in nitrogen (unreported decomposition of results in Table 5.7). This makes it relatively easy to target the sector causing the increase in pollution to try to reduce the impact of trade reform on emissions if the small increase is a problem.

5.5.3 Water use and pollution

Water withdrawals are reduced in all trade liberalization scenarios. Table 5.6 shows a reduction in withdrawals of 0.3 percent with Uruguay Round implementation. With the first stage of APEC, Table 5.7 shows that water withdrawals reduce by a further 1.1 percent and they continue to decline with APEC 2 as indicated in Table 5.8. These water use reductions are largely due to a reduction in paddy output in all trade liberalization scenarios modelled.

Most water pollutants also decline with Uruguay Round implementation as shown in Table 5.6. The declines are just under 1 percent for BOD, COD and dissolved solids but there is an increase of just over 1 percent in suspended solids. For the first stage of APEC liberalization, Table 5.7 reports reductions in all water pollutants of between 1.1 and 3.8 percent. These declines in water pollution are due primarily to reduced output in the other manufactured goods sector (unreported decomposition results). With the second stage of APEC, Table 5.8 reports an increase in most water pollutants of between 0.6 and 1.1 percent. From Table 5.5 we find that output of the other manufactured goods

sector increases in the APEC 2 simulation, though further decomposition of the results (unreported) suggests that the increased output in the pulp and paper sector has a much stronger effect on increasing water pollution.

5.6 What if trade reforms boost economic growth?¹⁵

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 may understate the extent of pollution that might occur (see Chapter Two). To get a feel of how large that bias might be, we re-ran the combined APEC 1 and APEC 2 liberalizations, 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 5.10, based on the output effects summarized in Table 5.9. Not surprisingly, that change in assumption raises the effect of liberalization on pollution on the assumption of no changes in environmental policy. Even so, the numbers are relatively small: air pollution is 12-15 per cent greater and water pollution 6-12 percent greater, than would have been the case in 2020.¹⁶ 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

¹⁵ This section draws on Strutt and Anderson (1998).

¹⁶ Instead of no more than 4 per cent as when we assume no growth effect of APEC reform (Strutt and Anderson 1998).

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 combined APEC 1 and 2 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.

5.7 Conclusions

Environmental side modules along with projections from a global trade model can demonstrate some of the potential environmental impacts of structural and policy change in Indonesia.

Given present environmental policies, structural change in Indonesia is likely to give rise to significant increases in environmental degradation. Despite the apparent increases in pollution that accompany growth, it is important both for the welfare of Indonesians and for the natural environment not to constrain economic growth in a poor country such as Indonesia (see Chapter Two). The modelling presented here captures some of the aggregate output, intersectoral composition and technology effects of growth. However, we do not fully capture linkages and interactions between growth and the environment. For example, we do not capture the likely changes to environmental policy with economic

growth. Growth in emissions can be moderated if we model improved environmental policies, such as production, consumption or pollution taxes. When the effects of these are sufficiently strong, it is possible to completely negate the increased per capita pollution to give an environmental Kuznets curve.

Trade liberalization results in much smaller and more ambiguous changes than did the structural change simulations. Trade liberalization itself is neither inherently environmentally damaging nor environmentally improving, though it has implications for the scale and composition of output. With trade liberalization expected to lead to economic growth, an increase in the scale of production is anticipated but the composition of output may change to more or less-degrading production. We showed that Uruguay Round liberalization will tend to reduce both air and water pollution, though by a lesser amount when China is included in the reform. APEC liberalization, on the other hand, tends to increase air pollution and reduce water pollution, though the second stage of APEC liberalization may increase both types of pollution. However, most increases in pollution are relatively small and are driven primarily by a small number of sectors. If the trade liberalization is accompanied by increased environmental taxes, this could help ensure no increase in emissions.

It is hoped that the results presented in this chapter contribute to understanding the environmental implications for Indonesia of structural and policy change. We have 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.¹⁷ Needless to say, caution should be used in interpreting the above results, particularly given the still poor quality of environmental data. The results presented here indicate sectors of particular concern, given available information. However, there will be other sectors and types of environmental damage that are not adequately represented here.¹⁸ It is hoped that work such as this will help to identify sectors of particular concern and also further open the debate, encouraging researchers to offer improved environmental parameters in crucial areas.

¹⁷ There are of course more sophisticated methods of projecting economic growth, using endogenous growth and incorporating imperfect competition and scale economies.

¹⁸ 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.

Table 5.1: Base and projected changes in the quantity of sectoral output evaluated at initial market prices, Indonesia, 1992, 2010 and 2020

	<i>1992 Output (US\$m)</i>	<i>2010 change (%)</i>	<i>2020 change (%)</i>
PDR	7,548	87	35
GRA	819	23	1
NGC	12,360	58	15
LVS	3,224	113	36
FOR	2,545	100	43
FSH	3,816	85	23
COL	824	124	49
OIL	7,375	114	64
GAS	6,108	103	59
OMN	3,073	131	82
PRF	23,972	87	34
TEX	14,096	449	177
LUM	7,227	73	32
PPP	2,728	331	132
PTC	5,324	253	121
CRP	9,373	282	120
NMM	1,860	267	125
OMF	20,013	375	201
EGW	2,764	268	118
CNS	22,113	241	125
TRT	25,007	304	120
OSP	36,212	293	114
OSG	8,582	447	61
Total, all sectors	226,963	215	95

Source: GTAP V3 database and authors' model results

Table 5.2: Recent and projected levels of atmospheric emissions in the base case, Indonesia, 1992, 2010 and 2020 (thousands of tons)

	<i>1992</i>			<i>2010</i>			<i>2020</i>		
	<i>carbon</i>	<i>sulphur</i>	<i>nitrogen</i>	<i>carbon</i>	<i>sulphur</i>	<i>nitrogen</i>	<i>carbon</i>	<i>sulphur</i>	<i>nitrogen</i>
PDR	1	0.0	0.1	2	0.0	0.1	3	0.0	0.2
GRA	16	0.0	0.9	20	0.0	1.1	21	0.0	1.2
NGC	241	0.3	14.0	378	0.5	22.0	415	0.5	24.2
LVS	310	0.4	17.9	677	0.8	39.1	931	1.1	53.8
FOR	246	0.3	14.4	485	0.6	28.3	682	0.8	39.8
FSH	531	0.6	31.1	882	1.1	51.6	1,014	1.2	59.3
COL	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
OMN	409	11.1	1.5	650	17.6	2.4	837	22.7	3.1
PRF	489	13.0	1.8	752	19.9	2.8	890	23.5	3.3
TEX	293	7.7	1.1	770	20.1	3.0	1,160	29.9	4.6
LUM	481	12.9	1.8	880	23.6	3.2	1,167	31.3	4.2
PPP	217	6.3	1.5	712	20.8	5.0	1,317	38.9	9.7
PTC	1,305	17.4	8.3	4,047	54.4	25.7	8,302	112.4	52.8
CRP	3,330	35.6	26.6	5,930	65.9	47.3	4,867	60.8	38.6
NMM	894	25.6	5.4	2,503	73.0	16.8	4,448	131.9	32.5
OMF	880	23.0	3.4	1,997	52.0	7.8	2,074	53.5	8.2
EGW	7,843	168.2	102.8	18,045	347.1	241.6	26,637	434.2	366.8
CNS	10,547	69.2	37.9	25,007	164.1	89.9	42,587	279.5	153.1
TRT	10,322	129.8	532.5	30,564	384.5	1,578.4	52,865	665.4	2733.0
OSP	193	1.2	0.8	559	3.4	2.2	943	5.7	3.7
OSG	709	4.1	2.8	2,882	16.8	11.4	3,724	21.6	14.8
Total	48,668	606	882	114,014	1,405	2,309	177,264	2,104	3,782

Source: Authors' model results.

Table 5.3: Recent and projected levels of water use and quality in the base case, Indonesia, 1992, 2010 and 2020

<i>Base level for 1992</i>	<i>Water in (millions of m³)</i>	<i>Water out (millions of m³)</i>	<i>BOD (kt)</i>	<i>COD (kt)</i>	<i>Dissolve d solids (kt)</i>	<i>Suspend ed solids (kt)</i>
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
<i>2010</i>	<i>Water in (millions of m³)</i>	<i>Water out (mil. m³)</i>	<i>BOD (kt)</i>	<i>COD (kt)</i>	<i>Dissolve d solids (kt)</i>	<i>Suspend ed solids (kt)</i>
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
<i>2020</i>	<i>Water in (millions of m³)</i>	<i>Water out (mil. m³)</i>	<i>BOD (kt)</i>	<i>COD (kt)</i>	<i>Dissolve d solids (kt)</i>	<i>Suspend ed solids (kt)</i>
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

Table 5.4: Decomposition of changes in pollution as a consequence of economic growth and structural change, Indonesia, 1992-2020

(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 effect	Intersectoral composition effect	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 5.5: Projected percentage changes in the quantity of sectoral output evaluated at initial market prices as a consequence of Uruguay Round and APEC trade reform, Indonesia, 2010 and 2020

	<i>Uruguay Round, 2010</i>		<i>APEC 1, 2010</i>	<i>APEC 2, 2020</i>
	(%)		(%)	(%)
	<i>UR</i>	<i>UR + China</i>	<i>APEC 1</i>	<i>APEC 2.</i>
PDR	-0.6	-0.3	-1.1	-0.7
GRA	3.2	4.7	9.3	7.5
NGC	-5.1	-4.6	-6.5	-6.4
LVS	-0.2	0.1	-0.8	2.4
FOR	-3.4	-1.1	3.8	-0.2
FSH	-1.1	-0.7	-2.6	-2.0
COL	-12.1	-7.1	7.2	8.0
OIL	-5.4	-3.3	0.6	0.1
GAS	-5.4	-3.4	-0.3	0.4
OMN	-8.1	-5.2	-1.2	-0.4
PRF	-0.6	-0.3	-1.2	-0.7
TEX	61.9	38.5	6.2	-1.5
LUM	-6.9	-2.4	10.4	0.2
PPP	-7.8	-3.7	2.0	2.7
PTC	0.9	0.5	-1.0	-0.9
CRP	1.1	2.5	2.5	3.4
NMM	-7.5	-4.4	4.2	13.8
OMF	-19.6	-12.3	-12.8	1.5
EGW	2.5	1.5	0.5	0.4
CNS	0.5	-0.1	-0.1	-1.0
TRT	-2.4	-1.3	2.0	1.6
OSP	-2.0	-1.4	0.7	0.2
OSG	-0.6	-0.5	-0.2	-0.7
Real GDP	1.9	1.4	0.84	0.27

Source: Authors' model results.

Table 5.6: Decomposition of pollution effects from Uruguay Round implementation (including China), Indonesia, 2010 (% change from 2010 baseline level shown in curved parentheses, % of the 1992-2010 change is in square parentheses)

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

Source: Authors' model results.

Table 5.7: Decomposition of pollution effects under first stage of APEC liberalization, Indonesia, 2010 (% change from 2010 baseline level shown in curved parentheses, % of the 1992-2010 change is in square parentheses)

	Total change	Aggregate activity	Intersectoral composition
Carbon (kt)	1,111 (1.0) [1.7]	956 (0.8) [1.5]	155 (0.1) [0.2]
Sulphur (kt)	18 (1.3) [2.3]	12 (0.8) [1.5]	6 (0.4) [0.8]
Nitrogen (kt)	38 (1.6) [2.7]	19 (0.8) [1.4]	19 (0.8) [1.3]
Water in (billion m ³)	-3 (-1.1) [28]	3 (0.8) [-21]	-6 (-1.9) [50]
Water out (billion m ³)	-0.04 (-3) [-5]	0.01 (0.8) [1]	-0.06 (-4) [-7]
BOD (kt)	-3 (-1.3) [-3.8]	2 (0.8) [2.5]	-5 (-2.1) [-6.2]
COD (kt)	-13 (-1.5) [-3.8]	7 (0.8) [2.1]	-20 (-2.3) [-5.9]
DS (kt)	-0.22 (-1.1) [1.3]	0.2 (0.8) [-1.0]	-0.4 (-2.0) [2.3]
SS (kt)	-22 (-3.8) [-20]	5 (0.8) [5]	-26 (-4.6) [-25]

Source: Authors' model results.

Table 5.8: Decomposition of pollution effects under second stage of APEC liberalization, Indonesia, 2020 (% change from 2020 baseline level shown in curved parentheses, % of the 2010-2020 change is in square parentheses)

	Total change	Aggregate activity	Intersectoral composition
Carbon (kt)	1,448 (0.8) [2.3]	485 (0.3) [0.8]	964 (0.5) [1.5]
Sulphur (kt)	35 (1.7) [5.0]	6 (0.3) [0.8]	29 (1.4) [4.1]
Nitrogen (kt)	49 (1.3) [3.4]	11 (0.3) [0.7]	39 (1.0) [2.6]
Water in (billion m ³)	-1.5 (-0.8) [-1.4]	0.5 (0.3) [0.5]	-2.0 (-1.0) [-1.8]
Water out (billion m ³)	0.013 (0.7) [3.2]	0.005 (0.3) [1.2]	0.008 (0.4) [2.0]
BOD (kt)	2.4 (1.1) [16]	0.6 (0.3) [4.0]	1.8 (0.8) [12]
COD (kt)	9.7 (1.1) [108]	2.4 (0.3) [27]	7.3 (0.8) [81]
DS (kt)	-0.06 (-0.9) [-0.5]	0.02 (0.3) [0.2]	-0.08 (-1.1) [-0.6]
SS (kt)	2.1 (0.6) [1.0]	1.0 (0.3) [0.5]	1.1 (0.3) [0.5]

Source: Authors' model results.

Table 5.9: Projected percentage changes in the quantity of sectoral output evaluated at initial market prices as a consequence of APEC reform with additional growth, Indonesia, 2020

	APEC liberalization, 2020 (with extra GDP growth of 0.5% pa in APEC economies)
Paddy rice	5.9
Other grains	22.6
Non-grain crops	-4.5
Livestock	13.2
Forestry	9.4
fisheries	5.8
Coal	31.1
Oil	11.9
Gas	11.1
Other minerals	8.3
Food processing	5.8
Textiles, clothing, leather	2.9
Wood products	11.5
Paper products	17.8
Petroleum & coal products	7.0
Chemicals, rubber & plastics	20.8
Non-metallic mineral products	33.6
Other manufactured products	7.4
Electricity, water & gas	10.7
Construction	5.9
Trade & transport	16.3
Other private services	12.1
Other public services	9.3
Real GDP growth	10.8

Source: Authors' model results.

Table 5.10: 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 (12) [16]	19,091 (11) [15]	2,051 (1) [2]
Sulphur (kt)	283 (14) [19]	227 (11) [15]	57 (3) [4]
Nitrogen (kt)	557 (15) [19]	407 (11) [14]	149 (4) [5]
Water in (billion m ³)	11 (6) [9]	21 (11) [17]	-9 (-5) [-8]
Water out (billion m ³)	0.15 (9) [13]	0.19 (11) [16]	-0.04 (-2) [-3]
BOD (kt)	27 (12) [39]	24 (11) [35]	3 (1) [4]
COD (kt)	104 (12) [31]	93 (11) [28]	11 (1) [3]
DS (kt)	0.4 (6) [2]	0.8 (11) [3]	-0.4 (-5) [-1]
SS (kt)	26 (7) [24]	39 (11) [37]	-14 (-4) [-13]

Source: Authors' model results.

Table 5.11: Decomposition of the total change in emissions (from Table 5.6) by sector from Uruguay Round implementation (including China), Indonesia, 2010

	<i>Carbon (kt)</i>	<i>Sulphur (kt)</i>	<i>Nitrogen (kt)</i>	<i>Water in (bm³)</i>	<i>Water out (bm³)</i>	<i>BOD (kt)</i>	<i>COD (kt)</i>	<i>DS (kt)</i>	<i>SS (kt)</i>
PDR	-0.01	0.00	0.00	-0.78	0.00	0.00	0.00	0.00	0.00
GRA	0.93	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
NGC	-17.33	-0.02	-1.01	0.00	0.00	0.00	0.00	0.00	0.00
LVS	0.95	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
FOR	-5.09	-0.01	-0.30	0.00	0.00	0.00	0.00	0.00	0.00
FSH	-6.35	-0.01	-0.37	0.00	0.00	0.00	0.00	0.00	0.00
COL	-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
OMN	-33.86	-0.92	-0.13	0.00	0.00	0.00	0.00	0.00	0.00
PRF	-2.03	-0.05	-0.01	0.00	0.00	-0.03	-0.05	-0.05	-0.07
TEX	296.17	7.71	1.15	0.11	0.11	12.20	48.81	0.00	49.57
LUM	-21.47	-0.58	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
PPP	-26.13	-0.76	-0.18	-0.02	-0.01	-4.08	-14.74	0.00	-3.05
PTC	21.45	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00
CRP	150.03	1.67	1.20	0.00	0.00	0.00	0.00	0.00	0.00
NMM	-108.88	-3.17	-0.73	0.00	0.00	0.00	0.00	0.00	0.00
OMF	-246.05	-6.40	-0.96	-0.09	-0.09	-10.14	-40.55	0.00	-41.18
EGW	276.08	5.31	3.70	0.00	0.00	0.00	0.00	0.00	0.00
CNS	-27.51	-0.18	-0.10	0.00	0.00	0.00	0.00	0.00	0.00
TRT	-385.10	-4.84	-19.89	0.00	0.00	0.00	0.00	0.00	0.00
OSP	-7.71	-0.05	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
OSG	-13.83	-0.08	-0.05	0.00	0.00	0.00	0.00	0.00	0.00
Total	-732.75	-7.74	-22.09	-0.78	0.01	-2.05	-6.53	-0.05	5.27

Source: Authors' model results.

6. SUMMARY AND FINAL REMARKS

6.1 Main findings

Market reforms such as trade liberalization are seen by some groups as adding to environmental damage through boosting income growth and structural change. Yet other groups claim that such changes may have positive as well as negative impacts on the natural environment. This thesis investigates the linkages between economic growth, trade policy and the environment to examine these conflicting claims, with particular attention to Indonesia.

In Chapter Two we develop a model of the theoretical foundations for negative and positive environmental impacts arising from economic growth. We demonstrate the potential importance of including environmental damage and feedback effects on production and show that policy changes may have unexpected results. For example, a “green” technology designed to enhance the environment, but ostensibly harming output growth rates, can *raise* output levels. On the other hand, a dirty technology designed to increase output levels can reduce the equilibrium levels of *both* output and environmental services. We conclude that policy changes that raise growth, such as trade liberalization, may have ambiguous effects on the natural environment.

In subsequent chapters we use a global computable general equilibrium model in an attempt to increase understanding of the direction and magnitude of change in environmental damage in Indonesia with trade reform. Chapter Three models land degradation in Indonesia and includes environmental feedback effects on production, which are likely to be particularly significant in natural resource based sectors such as agriculture. Using a modified version of the GTAP model, we find that Uruguay Round implementation is likely to lead to an increase in net erosion and the associated off-site damage in Indonesia. However this increase is extremely small, with the cost of damage caused by increased erosion amounting to less than 0.2% of the national economic welfare gain (as traditionally measured) from the Uruguay Round liberalization.

Chapter Four models structural growth and change between 1992 and 2020, both with and without the effects of Uruguay Round implementation and APEC trade reform. Large changes are projected for the structure of the global economy between 1992 and 2020. World output is projected to more than double and our results suggest that developing APEC regions will increase their contribution to world output by 130 percent during the period 1992-2020, while the contribution of Indonesia to global output almost trebles.¹ Trade reform, particularly multilateral trade liberalization, further enhances Indonesia's economic growth and development prospects. Uruguay Round implementation is projected to lead to a 1.9 percent increase in real GDP (a little lower if China is included). APEC liberalization is projected to give rise to an increase in real

¹ The adverse effects of the current financial crisis in East Asia are not included here, but are discussed by Anderson and Strutt (1998).

GDP of almost 1 percent for the first stage where developed economies fully liberalize and developing economies partially liberalize. There is a further 0.3 percent increase in GDP projected for the second stage of APEC reform, where developing economies complete their liberalization.

The projected changes in the economy, due to growth over the period and the implementation of trade agreements, have important implications for the level of pollution in Indonesia. Chapter Five uses environmental side modules in conjunction with projections from the global trade model to analyse the effects on water and air pollution. We analyse the contribution to environmental damage of changes in the aggregate level of output, the composition of that output, and the technology used to produce it. If present environmental policies remain unchanged, projected economic growth and structural change in Indonesia is likely to give rise to significant increases in environmental degradation. Of course this is not an argument against growth (indeed Chapter Two indicated the importance, both for the welfare of Indonesians and for the natural environment, of not constraining economic growth in a poor country like Indonesia). There may however be a need to introduce or strengthen the enforcement of property rights and environmental policies to internalize some of the currently non-marketed environmental damage.

The trade liberalizations slated for the next two decades result in much smaller and more ambiguous changes than does the structural change that will occur between 1992 and 2020. Trade liberalization itself is neither inherently environmentally damaging nor environmentally improving, though it has

implications for the scale and composition of output.² We find that Uruguay Round liberalization will tend to reduce both air and water pollution in Indonesia. APEC liberalization, on the other hand, may increase some forms of pollution, however, even in the very worst cases it only adds very slightly to environmental damage. The increases in pollution are relatively small and driven primarily by a small number of sectors, so if the trade liberalization is accompanied by increased environmental taxes, this could help ensure no increase in emissions. The economic gains from trade reforms, along with this scope for adopting well-targeted environmental policies, indicate that social welfare is almost certain to increase with trade reform, even when we include the potential costs of environmental damage in our analysis.

6.2 Limitations and future research directions

This kind of research is very much in its infancy; there are many future directions and areas where improvements can be made.

The modelling presented in Chapter Five captures some of the aggregate output, intersectoral composition and technology effects of growth. However, we do not fully capture linkages and interactions between growth and the environment. For example, we do not capture the likely changes to environmental policy with

² We assume that a change in trade policy does not change the technology with which output is produced. For a study that also models the responses of environmental policies to trade reform see Beghin et al. (1997).

economic growth. Endogenizing environmental policies to income growth,³ trade policy changes and changes in pollution would be a useful extension to this work. Growth in emissions can be moderated if we model improved environmental policies, such as production, consumption or pollution taxes.⁴ With no market for environmental damage, producers cannot be expected to autonomously employ less-damaging methods of production. However, if environmental damage taxes are imposed, incentives emerge for businesses to control the amount of environmental damage. Induced innovation theory suggests that the direction of technological advances may be driven by economic incentives (Hayami and Ruttan 1985); we have only attempted to capture the natural changes in technology over time.

More sophisticated modelling of changes in technology including those due to more stringent environmental policies is desirable. This would facilitate explicit modelling of other scenarios presented in Chapter Two such as “green” technologies. Such simulations may provide useful insights if, for example, the Government is considering encouraging what are ostensibly environmentally-sound innovations in one sector. Abler and Shortle (1995) and Coxhead and Jayasuriya (1994) discuss examples of unexpected results from technical change, where environmental innovations can actually lead to more net damage, which only becomes apparent when general equilibrium effects are included.

³ 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 (1998).

⁴ When the effects of these are sufficiently strong, it is possible to completely negate the increased per capita pollution to give an environmental Kuznets curve.

There have been attempts to incorporate environmental equations and parameters directly into a CGE model (for example Xie 1996, Beghin et al. 1996). This is difficult given the current paucity of environmental data and in the case of a global model, the difficulties are further magnified. In this study we have used side modules as a means of gaining insight into the direction and magnitude of change. As improved environmental data becomes available across regions, the environmental effects in other countries could be traced. In particular, improved modelling of air pollution across countries will be possible with the upgraded energy component of future versions of the GTAP database.⁵ More direct inclusion in the model of emissions and abatement activities may be desirable. For example the models can be modified to enable induced substitution towards less environmentally damaging output and the adoption of less-polluting technologies when environmental taxes are in place.

In this study, use Indonesia-specific pollution estimates, but marginal damage from environmentally degrading activities is assumed to be constant and directly related to output. It is clear, however, that many environmental effects are cumulative in nature and damage functions are likely to be non-linear. Economists have yet to deal well with issues such as cumulative damage and irreversible effects. Environmental thresholds and irreversible effects do not necessarily pose particularly complicated modelling problems; the difficulty is

⁵ 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 database are available at <http://www.agecon.purdue.edu/gtap/doe/index.htm>.

more that of finding reliable information and forecasts of such effects. Because of uncertain linkages, sensitivity analysis and caution are important, particularly where effects may be irreversible.

We conduct systematic sensitivity analysis on the key environmental feedback parameters in Chapter Three, however much more work in this area could be done. For example, Dasgupta and Heal (1979) suggest that assuming the elasticity of substitution is independent of the capital to resource ratio may be treacherous for exhaustible resources. Also, when the response of adding more pollutants to the environment is severely non-linear, at some point the effects may be so large as to not allow sufficient time for an economic response (Shane and von Witzke, 1993). Since the natural environment has some limited assimilative capacity for many forms of degradation, functions could be defined that, for example, assume little or no damage occurs initially but once a certain threshold is passed, the damage kicks in with an exponentially degrading effect on natural resources. Where activities are outside the range of available empirical evidence, qualitative research can determine the bounds of the relatively predictable range of environmental resource inputs and environmental damage outputs.

In the case of air and water pollution, we simply look at changes in physical pollution, whereas for land degradation we try to assess the monetary value of the damage. Interesting work is underway to improve monetary estimates of damage. In an ambitious study, Beghin et al. (1998) quantify the effect of environmental taxes and their interaction with trade policies on the environment,

public health and the economy. Cole et al. (1998) apply emission coefficients for expected Uruguay Round output changes and attempt to place a monetary value on the estimated change in emissions. Clearly this is a challenging area with the values open to question. However it is an additional step towards providing more complete information, and explicitly placing transparent values on emissions certainly opens the issue up to further debate and should improve understanding.

Further work will also be useful to further disaggregate the sectors and regions modelled to capture pollutant concentration implications. For example, as the sectoral disaggregation in GTAP increases, more detailed sectoral analysis is possible for Indonesia. The recently released Version 4 of GTAP has a much more detailed sectoral disaggregation, particularly for agriculture. This will enable finer analysis and targeting of key sectors. For example the inclusion of fruit and vegetables will facilitate improved focus on not just environmental but also food safety issues (Anderson and Strutt 1996). Although the intensity of farm chemical use in Indonesia is not especially high, the toxicity of chemicals used and the lack of training in safety and environmental precautions may lead to high levels of damage, and this could be an interesting area of research.

Some pollutants such as carbon are global and our analysis for Indonesia could be complemented with analysis of environmental effects in other regions to determine global outcomes. For other pollutants, such as sulphur and nitrogen oxides, the geographic distribution of emissions is much more important because high concentrations typically lead to damage. We are not able to

directly assess the regional concentration of pollutants in our current model. Much of current pollution occurs on Java and although industry is expected to spread to other islands in the future, Java will continue to dominate industrial production and provide a home to the majority of the population (Duchin et al. 1993). Hence most of the increases in emissions are likely to be concentrated in Java and pollution is already serious in Jakarta. A model that is disaggregated to cover the various regions of a country will help to facilitate this kind of analysis. It may be that a national level model is appropriate for more detailed regional work. For example the INDOGEM applied general equilibrium model of Indonesia could be adapted and used (Trewin, Erwidodo and Huang 1993, Erwidodo and Trewin 1994).⁶ This model has an attractive sectoral disaggregation including different types of regional rice production, irrigation, and farm chemicals and it could be extended to separate the key regions in Indonesia, using a new regionally disaggregated social accounting matrix for Indonesia (Warr and Azis 1997).

Anderson and Strutt (1996) discuss the potential for integrating a model such as INDOGEM with GTAP by ensuring there exists a version of INDOGEM that has an identical structure to that in the GTAP model. This would have clear advantages, and both models share a similar architecture which should make any extensions of INDOGEM relatively straightforward to replicate for other countries/regions in the GTAP model. The two models are complementary in many ways. The GTAP model could be used to simulate global changes such

⁶ Developed from a CGE model of Indonesia which focused mainly on the forestry sector (Dee 1991).

trade liberalization and forecasted growth, with the effects on Indonesia manifested as exogenous shocks in the INDOGEM model (see Adams et al. 1996 for an application of this top-down approach to Australia, and Trewin 1995 for a discussion of applying such an approach to Indonesia).

In addition to the challenges that lie ahead for improving our modelling and understanding of environmental damage, there are also challenges to improve the capabilities of available CGE models. In particular, we have used a comparative static model in the empirical part of this study and therefore may miss some of the important dynamic changes in the economy over time and due to trade reform. In Chapter Five we briefly discuss the potential effects when trade reform increases economic growth, however much more sophisticated modelling of the dynamics of the economy is desirable. Even within the comparative static model, there is plenty of room for improvement, particularly when projecting the global economy over long periods of time. For example, Chapter Four discusses the importance of the elasticities implicit in the global trade model used. There remains more work to be done to ensure that the implicit supply elasticities are appropriate and that the income elasticities capture the full extent of shifts in consumption patterns.

6.3 Final remarks

This thesis contributes to understanding the environmental implications for Indonesia of structural and policy change. We find that the environmental effects of trade reform may be positive or negative, but they are invariably extremely small relative to the base rates of environmental damage and to the change in environmental damage that will occur naturally as the economy grows and changes over time. The results presented here are consistent with other recent studies in the finding that trade reform is not likely to lead to large costs in terms of environmental damage (for example Cole et al. 1998 and Unterberdoerster 1998).

Research resources are scarce and it seems appropriate to invest some of them in broad-based analysis that includes macroeconomic and intersectoral effects, especially since some effects will not be captured in a partial equilibrium framework. Modelling environmental effects at the more aggregate level of course involves making careful tradeoffs and much remains to be learnt before many aspects of the environmental-economic nexus can be modelled accurately. However, high priority needs to be given to identifying areas of genuine concern and also to exposing the negative impacts that inefficient policies such as halting trade reform on environmental grounds will have. We hope that this study contributes to improved understanding of the environmental effects of growth and policy reform in general and for Indonesia in particular.

APPENDIX A: ENVIRONMENTAL EFFECTS OF AGRICULTURAL PRODUCTION¹

Even though the natural environment has proven to be very resilient to people's demands upon it, modern agricultural production is being perceived increasingly as imposing adverse cumulative effects on natural resources. The seriousness of the consequences of environmental degradation is not clear: on-site farm productivity effects are rarely quantified and are often masked by offsetting productivity gains from new technologies, and there is even less information about off-site environmental effects and consequences for non-farmers. Smith (1992, p. 1077-8) evaluates a large number of U.S. studies and concludes that "Including the in-stream effects of soil erosion, wetland conversion, and groundwater contamination, agriculture's crop-related activities yield environmental cost estimates that range from less than one per cent to over 40 per cent of the value of crops produced per acre on the land deemed responsible for these impacts". The following provides a brief description of the major effects as presently perceived, a summary of which is provided in Figure A. Environmentally degrading production inputs are shown in shaded boxes, with the negative environmental impacts in unshaded boxes and arrows indicating the direction of effects. Despite inevitable overlap, they are discussed under the headings of land, farm chemicals, water, and livestock.

LAND

Since most land to be used for agriculture (and introduced forests) has to be cleared of natural forest, that conversion yields logs and/or firewood but reduces natural plant and animal biodiversity, the area of natural wilderness, the traditional land-use rights and sacred sites of forest-dwelling and forest-adjacent communities, and the forests' capacity to absorb carbon dioxide and hence slow any global warming. Presumably the most suitable farm land is among that

¹ This appendix draws on Anderson and Strutt (1996).

cleared first, but further expansion of agriculture may eventually bring more ecologically fragile land into production.

Erosion is likely to be one of the largest environmental costs, with the reduction of vegetative cover, cultivation, and grazing all exposing the soil to erosion by wind and water. There may be a loss of productivity at the eroded site, damage caused by the transportation of soil, and harmful deposition in destinations such as irrigation systems and dams. On the other hand, eroded soil may add to agricultural land productivity elsewhere, the Nile Delta being an example. Erosion rates depend on factors such as the type of soil, slope of the land, vegetative cover, rainfall, wind pattern and tillage methods. While it is plausible that farmers will optimally control on-site erosion, losses in productivity may be so gradual that farmers fail to notice them, particularly if they are masked by yield-increasing technological advances.

The on-site cumulative effects of erosion cause yields on eroded ground to fall over time. Crosson (1986) summarizes the results of three U.S. studies and concludes that on-site losses in production due to erosion might add perhaps one per cent to the cost of crop production. He suggests, however, that the off-site costs of erosion might be much greater: between \$4 and \$17 billion annually in the United States alone, compared with on-site costs of around \$500 million (a total of between 0.12 and 0.42 per cent of GDP). Crude estimates in Costa Rica, Malawi, Mali and Mexico suggest that the loss of productive soil in developing countries, where agriculture is a much larger share of the economy, may be in the range of 0.5 to 1.5 percent of GDP (World Bank 1993, p.56).

Biological activity and soil aeration are necessary for moisture retention and for the uptake of nutrients by plants. Ploughing, heavy machinery and fallowing all contribute to the compaction of soil, resulting in a deterioration in soil structure. Nutrient depletion or "soil mining" takes place when nutrient losses from processes such as plant and animal uptake, soil erosion, and leaching, are not balanced with nutrient replacement by organic and inorganic fertilizers, as well as crop residues (Heerink et al. 1993, p.36). To a large extent these effects are

site-specific and eventually become evident to farmers, who may be expected to take such on-site costs into account in their decision-making (Barrett 1991).

Some of these environmental effects simply alter the demand for variable farm inputs, others alter as well the available stocks of primary sector capital (arable and pasture land, coastal wetlands, forests, fisheries). Care is needed in modelling these effects to ensure they are correctly specified.

FARM CHEMICALS

Farm chemicals can be a partial substitute for land and green manure. They include inorganic fertilizers as well as manufactured pesticides, fungicides, herbicides and veterinary chemicals. All have enabled increased agricultural yields, which has encouraged numerous governments to subsidize their use. But they are not without adverse environmental impacts.

Inorganic fertilizers are primarily nitrogen and to a lesser extent phosphate and potash. Run-off of these fertilizers can cause surface and ground water contamination. The greatest problem appears to be eutrophication, or overenrichment, caused by excessive nutrients in waterways. Associated problems include algal blooms which may be toxic, and excessive quantities of aquatic plants. When these plants die, deoxygenation of the water can result, with further adverse impacts on freshwater and marine life. Nitrate leaching also lowers the quality of drinking water and may cause soil acidification, which harms vegetation and reduces crop yields.

The environmental impacts of pesticides vary enormously. Effects depend on the toxicity and persistence of the pesticide, as well as the intensity and location of use, however, scientific evidence on the environmental and human health risks is limited. Pesticide application rates are said to be frequently excessive; it has been suggested, for example, that less than 0.1 per cent of the pesticides applied actually reach target pests (Pimentel and Levitan 1986, p.90). Damage could be greatly reduced if the most toxic and persistent pesticides were

avoided, if applications were more strategic, and if pesticide price subsidies were removed (and replaced with taxes appropriate to their off-site environmental damage). Seed breeding for pest tolerance provides another alternative to continued use of pesticides.

Pimentel et al. (1992) estimate the costs imposed by pesticide application in the U.S. to be at least \$8 billion annually,² of which two-fifths apparently affects agricultural production directly.³ Destruction of beneficial natural predators and parasites is seen as a major and increasing problem. Indonesia is a frequently cited example, where a dramatic increase in insecticide use caused the destruction of natural enemies of the brown planthopper. Brown planthopper populations exploded with such devastating results that the government banned the use of many pesticides and steered farmers towards an integrated pest management strategy (Saragih and Tampubolon 1993). Off-site costs of pesticide use include losses of fisheries, birds and animals as well as human health effects. The human health effects include effects on users in the field, on those living in the vicinity, and on consumers of food containing chemical residues. There may be some immediate effects on farm labour productivity too (Antle and Pingali 1994, p.18). Insufficient safety standards and knowledge of pesticide hazards, as well as poor labelling and illiteracy, are likely to be problematic in poor countries especially.

WATER

About 70% of current world water use is for irrigation (Shiklomanov 1990, p.39), and in developing countries the percentage is often even higher (e.g., 98% in Indonesia -- see World Bank 1994). Inappropriate irrigation can lead to waterlogging and salinization problems. Waterlogging occurs when water is applied in excess of what plants can absorb, and is a particular problem when

²This figure appears to suffer from some double-counting. For example, \$1800m is the estimated cost of monitoring and cleaning contaminated groundwater but if this were done, the human health effects would presumably be lower.

soil has poor drainage. Salinization may be induced or worsened by disturbing the hydrological balance of the soil. For example, water tables of saline water can rise as the result of clearing trees for crops and pastures that use less water. Where water tables are saline or move through areas of stored salt, saline ground water can rise and adversely affect the growth of many plants (ESD 1991, p.54). Neighbouring farmers may also be affected by the rising water-table. Difficulties arise in solving these problems optimally when property rights are not well defined, when the government subsidizes farm water use as it so often does, and/or when raised water tables and increased river salinity are non-point or are occurring so gradually that their damaging effects go undetected.

On the other hand, falling water tables may result from inappropriate rates of water use. Water use is unsustainable when rates of use are greater than recharge rates, especially for ground water which tends to accumulate over long periods of time. The vast Aral Sea, now partly a salty plain, provides stark evidence of the possible consequences of excessive water use. Desertification may occur when overuse of groundwater for irrigation causes water tables to fall. Once the water-retaining capacity of the soil is lost, it may be extremely difficult to revive. However, the effects of desertification are thought to be not as large and pervasive as those of salinization (World Bank 1993, p.5).

The increasing demands on water resources are being further aggravated by deteriorating water quality. Water holds and transports silt, salts, chemicals, and excess nutrients (not to mention industrial, household and human waste), so the lower the water resources of a region and/or the more agriculture reduces river flows, the less capacity the water has to assimilate contaminants or discharge them to the sea. Problems from irrigating with river water are exacerbated in the dry season if flows become insufficient to prevent inland penetration of salt water from the sea, as has been occurring increasingly near, e.g., Bangkok and Jakarta. Turbidity can lead to a decrease in biological activity. Active chemicals

³This is based on annual costs of \$942m from crop losses, \$30m in livestock product losses, \$320m in honeybee and pollination losses, \$1400m due to pesticide resistance and \$520m to loss of natural enemies (Pimentel et al. 1992, p.757).

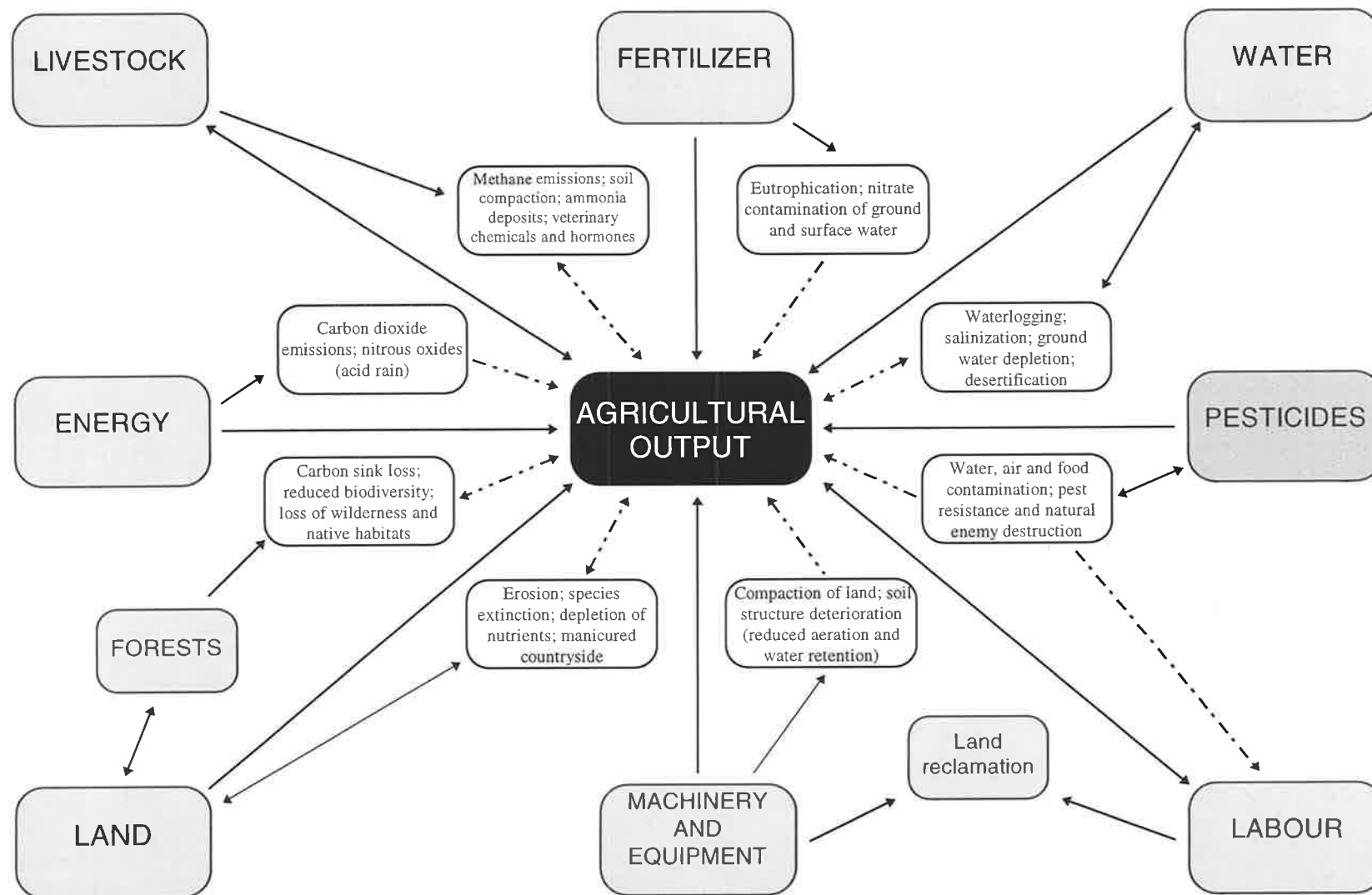
and excessive nutrients also harm animal and plant life, with degradation occurring both in fresh water and in the land or sea where pollutants eventually accumulate.

LIVESTOCK

Ruminant animals and leguminous pastures, together with biomass burning, nitrogenous fertilizers and rice production, are claimed to be significant contributors to greenhouse gases, particularly methane (ESD 1991, p.71). According to the World Resources Institute (1990, p.24), agricultural production and deforestation have each been contributing approximately one eighth of all greenhouse gases. Intensive livestock farming can lead also to large local environmental problems in terms of effluent disposal. Apart from air pollution, surface and groundwater contamination from excess nitrogen is possible: nitrates can harm vegetation and reduce the quality of drinking water. Extensive livestock grazing can result in soil compaction and, with excessive stocking rates, soil erosion. The latter on-site effects are a problem mainly where property rights are poorly defined such as in the Sahel.

In the extensively grazed areas where crops are grown in rotation with nitrogen-fixing leguminous pastures, such as in Argentina and Australia, there is no need for nitrogenous fertilizer and hence less nitrate pollution of water than in the more frequently cropped areas of the northern hemisphere and tropics.

Figure A: Main effects of agricultural production on the natural environment



Source: Anderson and Strutt, 1996.

Appendix B: Sectoral Definitions¹

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
Paddy Rice	Paddy rice	1. Paddy	1. Paddy	1110	Agricultural & livestock production (paddy rice only)
				1120	Agricultural services (servicing paddy rice production only)
Coarse grains	Wheat	2. Other food crops	2. Beans	1110	Agricultural & livestock production (wheat only)
				1120	Agricultural services (servicing wheat production only)
	Grains		3. Maize	1110	Agricultural & livestock production (grains except wheat & rice only)
				1120	Agricultural services (servicing production of grains, except wheat & rice only)
Non-grain crops	Non grain crops		4. Cassava, other roots	1110	Agricultural & livestock production (non-grain crops only)
			5. Vegetables and fruit		
			6. Other food crops	1120	Agricultural services (servicing non-grain crops production only)
		3. Estate crops	7. Rubber		
			8. Sugarcane		
			9. Coconuts		
			10. Oil Palm		
			11. Tobacco		
			12. Coffee		

¹ ISIC classes have been listed to correspond to the GTAP V3 aggregation and may not directly correspond to the other columns.

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
Livestock	Wool	4. Livestock, poultry and products	13. Tea		
			14. Cloves		
			15. Fibre crops		
			16. Other estate crops		
			17. Other agriculture		
			18. Livestock and its products	1110	Agricultural & livestock production (wool only)
				1120	Agricultural services (servicing wool production only)
	Other livestock		19. Meat and entrails	1110	Agricultural & livestock production (other livestock production only)
			20. Poultry and its products	1120	Agricultural services (servicing other livestock production only)
				1130	Hunting, trapping & game propagation
Forestry	Forestry	5. Forest products	21. Wood	1210	Forestry
			22. Hunting/other forest products	1220	Logging
Fisheries	Fisheries	6. Fisheries	23. Sea fish and other sea products	1301	Ocean and coastal fishing
				1302	Fishing n.e.c.
Coal	Coal	7. Coal	24. Coal and metal ore mining	2100	Coal mining
				3540	Manufacture of miscellaneous products of petroleum and coal (briquettes only) **
Oil	Oil	8. Crude oil	25. Crude oil, natural gas, geothermal	2200	Crude petroleum & natural gas production

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
Gas	Gas	9. Natural gas		2200	Crude petroleum & natural gas production (gas only)
				3530	Petroleum refineries (LPG only) **
Other minerals	Other minerals	10. Other mining	24. Coal and metal ore mining 26. Chemicals, other mining	2301	Iron ore mining
				2302	Non-ferrous ore mining
				2901	Stone quarrying, clay and pits
				2902	Chemical and fertiliser mineral mining
				2903	Salt mining
				2909	Mining and quarrying n.e.c.
Food processing	Processed rice	11. Food, beverages and tobacco	27. Manufactured food products	3116	Grain mill products (processed rice only)
	Meat products		28. Manufacture of oil and fat	3111	Slaughtering, preparing and preserving meat
	Milk products		29. Rice milling and husking	3112	Manufacture of dairy products
	Other food products		30. Manufacture of flour	3113	Canning and preserving of fruits and vegetables
				3114	Canning, preserving & processing of fish, crustaceans and similar foods
				3115	Manufacture of vegetable and animal oils & fats
				3116	Grain mill products (except processed rice)
				3117	Manufacture of bakery products
				3118	Sugar factories and refineries

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
				3119	Manufacture of cocoa, chocolate & sugar confectionery
				3121	Manufacture of food products n.e.c.
				3122	Manufacture of prepared animal feeds
	Beverages and tobacco		31. Sugar factory	3131	Distilling, rectifying & blending spirits
			32. Manufacture of other food products	3132	Wine industries
			33. Manufacture of beverages	3133	Malt liquors and malt
			34. Manufacture of cigarettes	3134	Soft drinks & carbonated waters industries
				3140	Tobacco manufactures
Textiles	Textiles	17. Other manufacturing	35. Yarn and cleaning kapok	3211	Spinning, weaving & finishing textiles
				3212	Manufacture of made-up textile goods excluding wearing apparel
				3213	Knitting mills
				3214	Manufacture of carpets & rugs
				3215	Cordage, rope & twine industries
				3219	Manufacture of textiles n.e.c.
	Wearing apparels		36. Manufacture of textiles, wearing apparel	3220	Manufacture of wearing apparel, except footwear
	Leather etc		42. Manufacture of rubber and plastic	3231	Tanneries & leather finishing
				3232	Fur dressing & dyeing industries
				3233	Manufacture of products of leather & leather

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
					substitutes, except footwear and wearing apparel
				3240	Manufacture of footwear, except vulcanised or moulded rubber or plastic footwear
Wood products	Lumber	12. Wood products	37. Manufacture of bamboo, wood	3311	Sawmills, planing & other wood mills
				3312	Manufacture of wooden & cane containers & small cane ware
				3319	Manufacture of wood & cork products n.e.c.
				3320	Manufacture of furniture & fixtures, except primarily of metal
Paper	Pulp paper etc	13. Pulp, paper and products	38. Manufacture of paper etc	3411	Manufacture of pulp, paper & paperboard
				3412	Manufacture of containers & boxes of paper and paperboard
				3419	Manufacture of pulp, paper & paperboard articles n.e.c.
				3420	Printing, publishing & allied industries
Petroleum and coal	Petroleum and coal	18. Petroleum refining	41. Petroleum and refinery	3530	Petroleum refineries (except LPG) **
				3540	Manufacture of miscellaneous products of petroleum and coal (except briquettes) **

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
Chemicals, rubber and plastics	Chemicals, rubbers and plastics	14. Fertilizer and pesticides	39. Manufacture of fertilizers and pesticides	3511	Manufacture of basic industrial chemicals except fertilisers
		15. Chemicals	40. Manufacture of chemicals	3512	Manufacture of fertilisers and pesticides
				3513	Manufacture of synthetic resins, plastic materials and man-made fibres except glass
				3521	Manufacture of paints, varnishes and lacquers
				3522	Manufacture of drugs and medicines
				3523	Manufacture of soap and cleaning preparations, perfumes and cosmetics
				3529	Manufacture of chemical products n.e.c.
				3551	Tyre and tube industries
				3559	Manufacture of rubber products n.e.c.
				3560	Manufacture of plastic products n.e.c.
Nonmetallic minerals	Nonmetallic minerals	16. Cement and limestone	43. Manufacture of non metal products	3610	Manufacture of pottery, china and earthenware
			44. Manufacture of cement	3620	Manufacture of glass and glass products
				3691	Manufacture of structural clay compounds
				3692	Manufacture of cement, lime and plaster
				3699	Manufacture of non-metallic mineral products n.e.c.
Other manufactured products	Primary ferrous metals	17. Other manufacturing	45. Manufacture of basic iron and steel	3710	Iron and steel basic industries
	Nonferrous metals		46. Manufacture of non ferrous base metals	3720	Non-ferrous metal basic industries

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
	Fabricated metal products			3811	Manufacture of cutlery, hand tools and general hardware
				3812	Manufacture of furniture and fixtures primarily of metal
				3813	Manufacture of structural metal products
				3819	Manufacture of fabricated metal products except machinery & equipment n.e.c.
	Transport industries		47. Manufacture of fabricated metal products	3841	Ship building and repairing
				3842	Manufacture of railroad equipment
				3843	Manufacture of motor vehicles
				3844	Manufacture of motorcycles and bicycles
				3845	Manufacture of aircraft
				3849	Manufacture of transport equipment n.e.c.
	Machinery and equipment		48. Manufacture of machinery, electrical appliances	3821	Manufacture of engines and turbines
				3822	Manufacture of agricultural machinery and equipment
				3823	Manufacture of metal and wood working machinery
				3824	Manufacture of special industrial machinery and equipment except metal and wood working machinery

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
				3825	Manufacture of office, computing and accounting machinery
				3829	Machinery and equipment except electrical n.e.c.
				3831	Manufacture of electrical industrial machinery and apparatus
				3832	Manufacture of radio, television and communication equipment and apparatus
				3833	Manufacture of electrical appliances and housewares
				3839	Manufacture of electrical apparatus and supplies n.e.c.
				3851	Manufacture of professional and scientific, and measuring and controlling equipment, n.e.c.
				3852	Manufacture of photographic and optical goods
				3853	Manufacture of watches and clocks
	Other manufacturing		49. Manufacture of transport equipment	3901	Manufacture of jewellery and related articles
			50. Manufacture of other products	3902	Manufacture of musical instruments
				3903	Manufacture of sporting and athletic goods
				3909	Manufacturing industries n.e.c.

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
Electricity, water and gas	Electricity, water and gas	19. Liquified natural gas		4101	Electric light and power
		20. Electricity	51. Electricity, gas and water supply	4102	Gas manufacture and distribution
		21. Gas utilities		4103	Steam and hot water supply
		22. Water utilities		4200	Water works and supply
Construction	Construction	23. Construction	52. Construction	5000	Construction
Trade and transport	Trade and transport	24. Wholesale and retail trade	53. Trade	6100	Wholesale trade
		25. Restaurants and hotels	54. Restaurant and hotel	6200	Retail trade
		26. Transport and communications	55. Railway transport	6310	Restaurants, cafes, and other eating and drinking places
			56. Road transport	6320	Hotels, rooming houses, camps and other lodging places
			57. Sea, water, lake transport	7111	Railway transport
			58. Air transport	7112	Urban, suburban and inter-urban highway passenger transport
			59. Services allied to transport	7113	Other passenger land transport
			60. Communications	7114	Freight transport by road
				7115	Pipeline transport
				7116	Supporting services to land transport
				7121	Ocean and coastal transport
				7122	Inland water transport
				7123	Supporting services to water transport
				7131	Air transport carriers
				7132	Supporting services to air transport
				7191	Services incidental to transport

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
				7192	Storage and warehousing
				7200	Communication
Other services: private	Other services, private	27. Real estate, financial and business	61. Financial intermediate		0 Activities not adequately defined
				8101	Monetary institutions
				8102	Other financial institutions
				8103	Financial services
				8200	Insurance
				8310	Real estate
				8321	Legal services
				8322	Accounting, auditing and bookkeeping services
				8323	Data processing and tabulating services
				8324	Engineering, architectural and technical services
				8325	Advertising services
				8329	Business services, except machinery and equipment rental and leasing, n.e.c.
				8330	Machinery and equipment rental and leasing
				9411	Motion picture production
				9412	Motion picture distribution and projection
				9413	Radio and television broadcasting
				9414	Theatrical producers and entertainment services
				9415	Authors, music composers and other independent artists n.e.c.

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
				9420	Libraries, museums, botanical and zoological gardens, and other cultural services, n.e.c.
				9490	Amusement and recreational services n.e.c.
				9511	Repair of footwear and other leather goods
				9512	Electrical repair shops
				9513	Repair of motor vehicles and motorcycles
				9514	Watch, clock and jewellery repair
				9519	Other repair shops n.e.c.
				9520	Laundries, laundry services, and cleaning and dyeing plants
				9530	Domestic services
				9591	Barber and beauty shops
				9592	Photographic studios, including commercial photography
				9599	Personal services n.e.c.
Other services: government	Other services, government	28. Public administration and defence	63. General government defence	9100	Public administration and defence
		29. Social and other services	64. Social and community	9200	Sanitary and similar services
			65. Other services	9310	Education services
		30. Unspecified	66. Unspecified services	9320	Research and scientific institutes
				9331	Medical, dental and other health services
				9332	Veterinary services
				9340	Welfare institutions
				9350	Business, professional and labour associations
				9391	Religious organisations

Aggregation used in Chapters 3,4 and 5	GTAP V3 sectoral aggregation	Duchin et al. sectoral aggregation	BPS Classification	ISIC Class	ISIC Description
	Ownership of dwellings		62. Real estate and business	na	9399 Social and related community services n.e.c. 9600 International and other extra-territorial bodies
				na	na

Source: Duchin et al. (1993), McDougall (1997), Warr and Azis (1997).

Appendix C: Import Tariff Rates in Indonesia Pre- and Post-Reforms, by Sector, 2010 (per cent)

	2010 base	2010 after UR	2010 after UR and APEC first stage libn.
Paddy rice	9.0	9.0	3.6
Coarse grains	0.0	0.0	0.0
Non-grain crops	54.7	38.3	15.3
Livestock	4.8	4.8	2.0
Forestry	14.4	14.4	5.9
Fisheries	29.8	29.8	11.9
Coal	5.0	5.0	2.0
Oil	0.0	0.0	0.0
Gas	5.0	5.0	2.0
Other minerals	4.9	4.9	2.4
Food processing	12.3	11.3	4.8
Textiles, clothing, leather	28.7	22.5	9.2
Wood products	34.4	31.0	12.4
Paper products	8.0	8.0	3.6
Petroleum & coal products	4.7	4.7	1.9
Chemicals, rubber & plastics	6.6	6.6	2.7
Non-metallic mineral products	14.1	12.9	5.2
Other manufactured products	15.6	15.4	6.2
Electricity, water & gas	0.0	0.0	0.0
Construction	0.0	0.0	0.0
Trade & transport	0.0	0.0	0.0
Other private services	0.0	0.0	0.0
Other public services	0.0	0.0	0.0

Source: GTAP data base and authors' model results.

Appendix D: Air and Water Pollution Coefficients for Indonesia: 1992, 2010 and 2020

(a) 1992 environmental coefficients

1992	Carbon	Sulphur	Nitrogen	Water in	Water out	BOD	COD	DS	SS
	(t/US\$m)	(t/US\$m)	(t/US\$m)	million m ³ /US\$m	million m ³ /US\$m	g/cubic m	g/cubic m	g/cubic m	g/cubic m
PDR	0.2	0.00	0.01	41.475					
GRA	19.5	0.02	1.13						
NGC	19.5	0.02	1.13						
LVS	96.1	0.12	5.55	0.0024					
FOR	96.7	0.12	5.64						
FSH	139.2	0.17	8.14						
COL	1036.1	30.56	7.01						
OIL	605.1	7.24	4.21						
GAS	670.6	0.13	6.42						
OMN	133.1	3.60	0.49						
PRF	20.4	0.54	0.08	0.0052	0.0041	211.8	306.0	378.0	503.4
TEX	20.8	0.54	0.08	0.0073	0.0073	176.0	704.0		850.0
LUM	66.5	1.78	0.24						
PPP	79.6	2.30	0.53	0.0795	0.0356	662.0	2230.0		717.6
PTC	245.1	3.26	1.55						
CRP	355.3	3.80	2.84	0.0005	0.0005	8.3	13.5		3.5
NMM	480.8	13.74	2.89						
OMF	44.0	1.15	0.17	0.0153	0.0153	176.0	704.0		850.0
EGW	2837.2	60.85	37.18						
CNS	477.0	3.13	1.71						
TRT	412.8	5.19	21.29						
OSP	5.3	0.03	0.02						
OSG	82.6	0.48	0.33						

(b) 2010 environmental coefficients

2010 Carbon	Sulphur	Nitrogen	Water in	Water out	BOD	COD	DS	SS
(t/US\$m)	(t/US\$m)	(t/US\$m)	million m ³ /US\$m	million m ³ /US\$m	g/cubic m	g/cubic m	g/cubic m	g/cubic m
PDR	0.2	0.00	0.01	21.242				
GRA	19.4	0.02	1.13					
NGC	19.4	0.02	1.13					
LVS	98.5	0.12	5.70	0.0023				
FOR	95.2	0.11	5.55					
FSH	125.3	0.15	7.33					
COL	517.8	15.27	3.50					
OIL	582.7	6.97	4.06					
GAS	494.8	0.10	4.74					
OMN	91.5	2.48	0.34					
PRF	16.8	0.45	0.06	0.0030	0.0023	118.7	167.1	192.9
TEX	9.9	0.26	0.04	0.0036	0.0036	114.3	457.1	464.3
LUM	70.2	1.88	0.26					
PPP	60.6	1.77	0.43	0.0442	0.0223	425.5	1535.7	318.0
PTC	215.7	2.90	1.37					
CRP	165.7	1.84	1.32	0.0003	0.0003	8.3	13.5	3.5
NMM	366.4	10.68	2.45					
OMF	21.0	0.55	0.08	0.0076	0.0076	114.3	457.1	464.3
EGW	1775.5	34.16	23.77					
CNS	331.6	2.18	1.19					
TRT	302.7	3.81	15.63					
OSP	3.9	0.02	0.02					
OSG	61.4	0.36	0.24					

(c) 2020 environmental coefficients

2020	Carbon	Sulphur	Nitrogen	Water in	Water out	BOD	COD	DS	SS
	(t/US\$m)	(t/US\$m)	(t/US\$m)	million m ³ /US\$m	million m ³ /US\$m	g/cubic m	g/cubic m	g/cubic m	g/cubic m
PDR	0.2	0.00	0.01	10.002					
GRA	19.4	0.02	1.13						
NGC	19.4	0.02	1.13						
LVS	99.9	0.12	5.78	0.0023					
FOR	94.3	0.11	5.50						
FSH	117.5	0.14	6.87						
COL	229.9	6.78	1.56						
OIL	570.3	6.82	3.97						
GAS	397.2	0.08	3.81						
OMN	68.4	1.85	0.25						
PRF	14.8	0.39	0.06	0.0017	0.0014	67.0	90.0	90.0	85.1
TEX	3.9	0.10	0.02	0.0016	0.0016	80.0	320.0		250.0
LUM	72.3	1.94	0.26						
PPP	50.1	1.48	0.37	0.0245	0.0148	294.1	1150.0		96.0
PTC	199.3	2.70	1.27						
CRP	60.4	0.75	0.48	0.0001	0.0001	8.3	13.5		3.5
NMM	302.9	8.98	2.21						
OMF	8.3	0.21	0.03	0.0033	0.0033	80.0	320.0		250.0
EGW	1185.7	19.33	16.33						
CNS	250.8	1.65	0.90						
TRT	241.6	3.04	12.49						
OSP	3.1	0.02	0.01						
OSG	49.6	0.29	0.20						

Source: These environmental coefficients are derived from Duchin et al. (1993), as described in Chapter 5.

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