AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

A study by the Department of Science and the Environment in consultation with Commonwealth departments and agencies

MATCHING ECONOMIC AND ENVIRONMENTAL FUTURES

by

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and

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The views expressed in this paper do not necessarily reflect the opinions of the Department of Science and the Environment, nor of the Australian Government.

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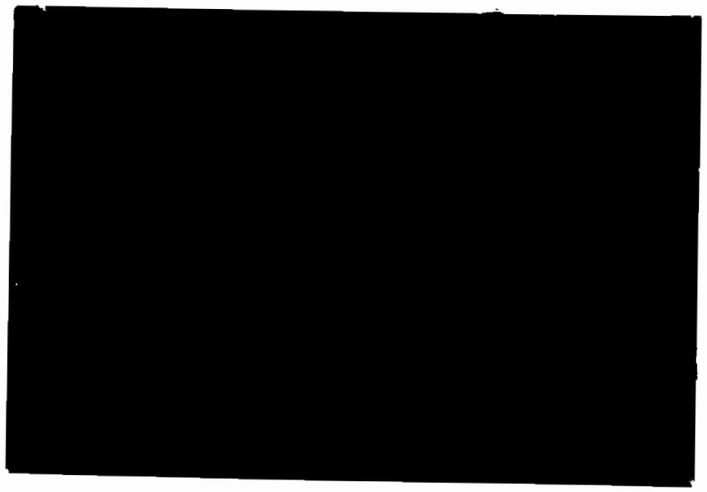
SARUM is a world econometric model developed by the System Analysis Research Unit of the UK's Department of the Environment, in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The world can be regionalised into twelve regions and a number of industrial and agricultural activities.



AREAM is the Australian version of SARUM for the analysis of Australian Resources and Environmental Assessment. The project was formulated in the light of a need to assess the impact of world change on the development of the Australian environment and its natural resources. In order to be able to look at environmental factors, SARUM is extended by the addition of an environment sector and the demographic sector is endogenised.

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ABSTRACT

Any assessment of the likely condition of the Australian environment toward the year 2000 would require accounting for the impacts of world economic development and demographic change. Within this context, this paper attempts to account for the environmental impacts that may arise in relation to a global scenario characterised by low economic growth rates over the next twenty years. To narrow the context of economic development further, we consider the implications for the Australian environment of a possible economic community formed by a number of West Pacific nations.

In relation to these possible economic futures an attempt is made to estimate the economic costs required to achieve a range of fixed reductions in environmental stress. This is done by linking, within a model of the global economic system, sets of relationships descriptive of the economic structure and environmental condition in Australia. In effecting this link we consider applications of the polluter-pays principle in which certain pollution abatement measures are required of stress-producing activities.

Specifically, this model is used to compute the trade-offs between the reduction of environmental stress and the costs of control in relation to coal developments in the energy sector. The effects of these measures on the Australian economic system, in terms of measures reflecting the standard of living of the population and levels of employment, are then described. The model is also used to throw light on the question of whether the increase in the production of pollution-control equipment balances the loss of production in the industries responsible for environmental stress. An attempt is also made to address questions on the effectiveness of the polluter-pays principle recently posed by the OECD.

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1. INTRODUCTION

The effects of changing global economic conditions are likely to hold significant implications for the state of the environment in countries, like Australia, which are continuing to expand their activities in international trade. This paper considers a means of assessing these implications: through extension of an existing model of the global economic system and its use of natural resources. Effects on the Australian environment of trade liberalisation in the West Pacific region are explored relative to a scenario of low rates of global economic growth prevailing over the next 30 or so years. Within this context the model is used to estimate the costs and benefits of reducing environmental stress. Specifically, the economic consequences of applying the polluter-pays principle as a policy of environmental protection are estimated in terms of its effects on gross consumption per capita and employment by industry sector. The model is also used to consider whether the increase in the production of pollution-control equipment balances the loss of production in industries causing environmental stress.

2. THE MODEL

Several models of the global economic system were developed in the 1970s. Only one, however, was suitable for extension to the quantification

of environmental stress.[1] The resulting model has been used to explore the interaction between international trade and environmental pollution in Australia. This model is referred to as the Australian Resource and Environmental Assessment Model - AREAM.

AREAM represents the global economic system and its use of natural resources by a set of differential equations which are integrated to give the future state of the system. In general, the equations are based on well-tried economic theories. However, by designing the equations so that the properties of the system tend towards their equilibrium values with delays governed by parameters of the system, the assumptions of general equilibrium theory have been largely eschewed. That is prices are not adjusted to equilibrate supply and demand at fixed time intervals, but rather recognise the many factors that inhibit the instantaneous clearing of markets. System parameters are chosen to match the behaviour of the model to that of reality.

The economic system can be subdivided into a variable number of <u>regions</u> corresponding to nations or groups of nations whose evolution in economic terms are likely to be roughly homogeneous. Production within regions is disaggregated into <u>sectors</u> corresponding to different types of production activity. Activities of the population are modelled by considering their behaviour as consumers, producers and investors. In studies to-date disaggregation has been problem-oriented. For example, in a study of the constraints imposed by finite land resources, land-rich nations would be grouped together, and separated from land-hungry nations. The output of the sectors is disaggregated into <u>commodity</u> mixes, chosen to be as homogeneous as possible or at least influenced in the same way by the expected depletion of resources under study. Commodities

may be consumed either by the consumer or by sectors as raw materials.

The primary purpose of AREAM is to study the effects of depletion of the earth's resources on the Australian environment. These resources may be assets such as reserves of cultivable land or fossil fuels, or something less definable such as the capacity of the environment to absorb and dissipate pollution. Depletion may be <u>resource-limited</u>, where the costs of production rise with every unit produced, or <u>flow-limited</u>, where costs rise with the rate of production. The effects of this depletion are propogated through the system by the increase in costs giving rise to increases in price, which will, directly or indirectly, reduce the demand and encourage alternative technologies.

The study of the inter-relationships between the economy and the environment covers such a wide range that it is impossible for one model to provide a comprehensive coverage. Thus, it is always essential when using a model to tackle problems to which it is well suited; different areas of study will require different approaches. A first useful step in narrowing down the study area is to distinguish between environmental stress and environmental impact, or response. Stress relates to human activity which affects the environment, whereas the consequential effects on the environment and the ways in which it responds are referred to by the term environmental impact. For example, the emission of sulphur dioxide from a coal-burning power station is an environmental stress, but the effect on river fish of the resulting sulphuric acid in the rain is an impact. Ultimately, interest will focus on the response of the environment; it is the deleterious impacts which are to be avoided or borne for the sake of some greater activity.

Stresses which are part of an ecological equilibrium do not usually give rise to great concern; for example, the activities of hunter-gatherer societies.[2]

The analysis of environmental impact involves many branches of science such as meteorology, ecology, chemistry and medicine. However vital those studies are, they cannot proceed without knowing the size and location of the stresses. Since most stresses are intimately bound up with economic activity, any assessment of future environmental stresses requires quantitative economic projections. AREAM provides quantitative projections of many economic variables and so is a suitable tool for providing estimates of future stress levels. It should be emphasised here that long-term economic models cannot provide forecasts; the vagaries of world politics can confound any prediction. Therefore such models can only be used for providing conditional forecasts, answering "What if?" questions. The set of assumptions needed to perform a model simulation is usually termed a scenario. Several scenarios are discussed in the next section where it will be seen that very different futures can arise from different assumptions. The value of modelling exercises lies in the help they give to understanding a complex system where many interactions are involved.

Many important stresses are associated with direct release of substances or energy into the environment, for instance solid wastes from mining and waste heat from power stations. The laws of conservation of matter and energy allow a self-consistent material-energy balance approach to be used.[3] Figure 1 depicts a subsystem of material or energy flows and the balances established within the "environment-economy" system. The flow of raw materials from the environment, A, taking the role of supplier (e.g. minerals extractions), is transformed

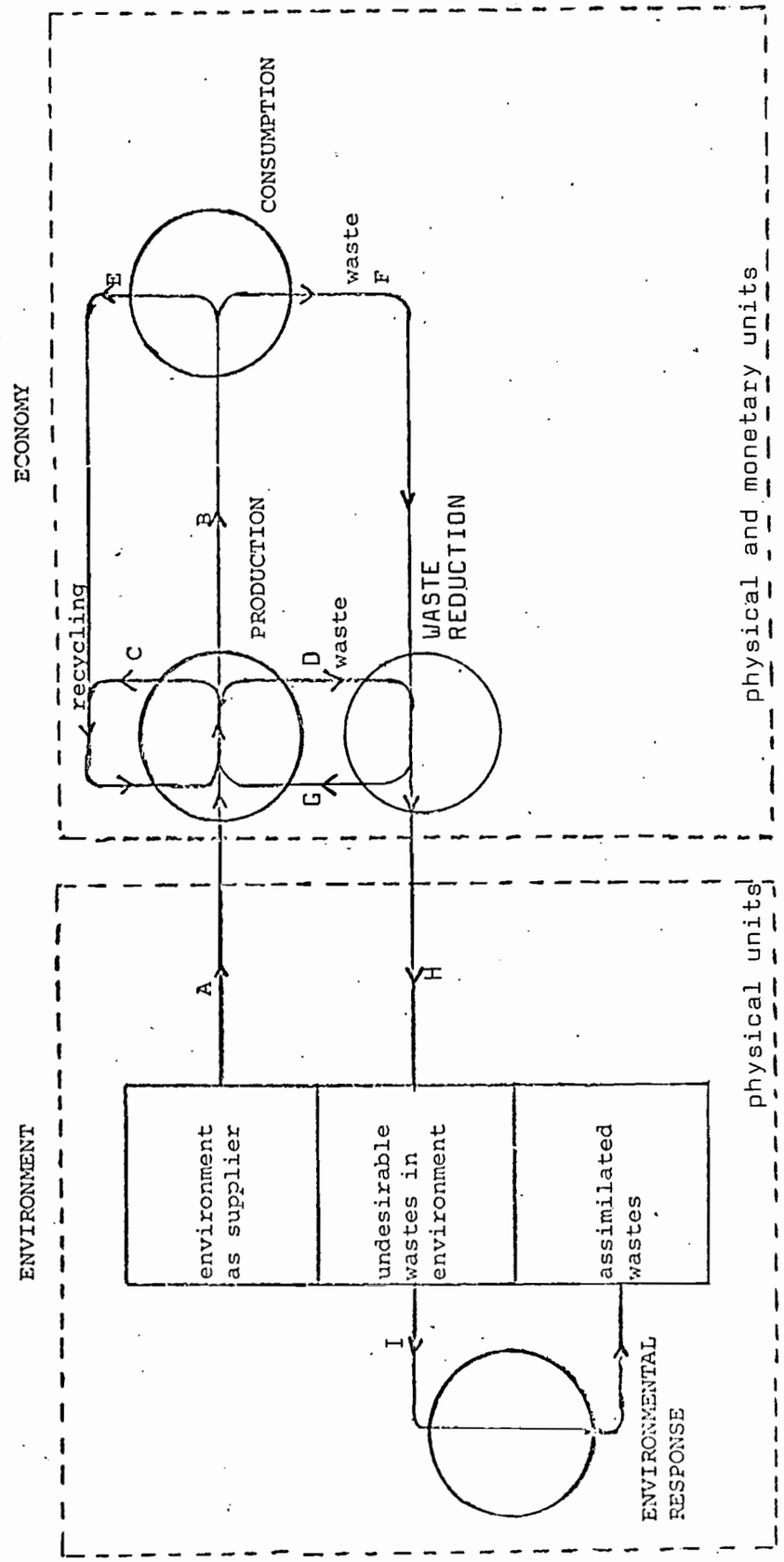


FIGURE 1 MATERIAL/ENERGY FLOW IN THE ENVIRONMENT-ECONOMY SYSTEM

by the production sector into goods for consumption, B, and waste is either discharged, D, or recycled C. The flow to consumption is eventually discarded, F, or recycled E. There is obviously some build-up in these sectors associated with capital equipment in the production process and consumer durables. However, it can reasonably be assumed that all human artefacts have a finite life and are eventually discarded or recycled. The total waste flow, H, returns to the environment. Some of these wastes, I, can be assimilated at varying speeds, by the environment.

Since the response of the environment to stresses is a complicated topic requiring specialist knowledge the scope of the present analysis is restricted to the workings of the economy and its direct connections with the environment. However, it is possible to use the model to examine how environment protection policies can reduce stress on the environment. For example, if the polluter-pays principle (PPP) is applied then certain pollution abatement measures are required of stress-producing activities. Thus the costs, G, of abatement can be passed back to the polluting industry with the consequential reduced stress, H, on the environment. These pollution control measures have to be paid for, with the resulting increase in the costs of production eventually being passed through to exports and home consumers. By closing such feedback loops between the environment and different parts of the economy, for example, the primary producers, the intermediate manufacturing industries or the final consumers, the model can be used to compute trade-off curves between stress reduction and control costs. The effects on the structure of the economy can then be investigated.

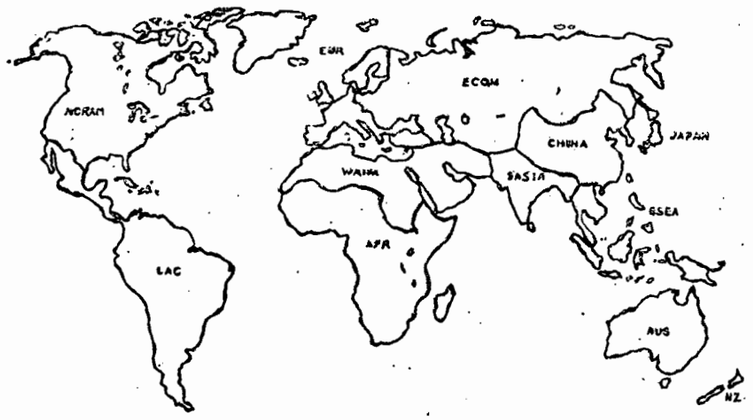
The stresses which are to be investigated must depend on economic variables available in the model. In

many cases a simple coefficient will suffice, for example the number of tonnes of sulphur dioxide released for every tonne of coal burnt. However, more complicated relationships could be used which take into account such things as the increase in mine wastes per tonne of metal content as ore grades decline. Assumptions can also be made about how these coefficients may change over time, perhaps as a result of greater pollution controls or an increase in recycling. Such assumptions will form part of the scenario to be considered here and are an essential component of any analysis and discussion of the final results.

3. AN ECONOMIC CONTEXT

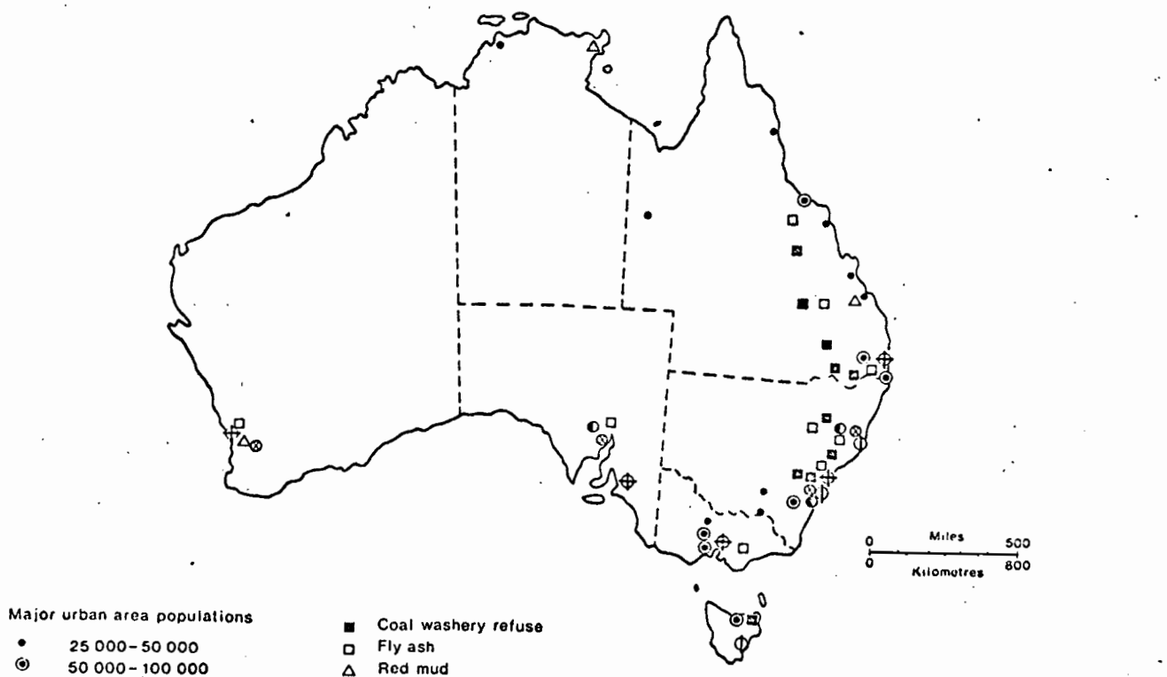
A reference scenario was evaluated to provide a basis for comparison among several other variant scenarios, all of which used the regional disaggregation shown in Figure 2. Such an approach is useful for drawing inferences about what are the important factors in problems under consideration. The reference experiment used the low rates of economic growth underlying one of the major scenarios evaluated by a global research project recently completed by the OECD - the Interfutures Project.[4] These growth rates are approximately based on the extrapolation of trends indicated in the late 1970s. The trade assumptions of the reference experiment differ from those of the OECD scenario, however. In the former the trade biases[5] are assumed constant rather than falling. The biases represent the factor by which any particular trade flow (e.g. food exports from Australia to Western Europe) is less than that which would be expected in a perfect, free-trade world, having made due allowance for price differences. Trade occurs between economic sectors within the regions such as those shown in Figure 2. The sectors within the current version of AREAM cover energy, minerals, manufactures, machinery,

FIGURE 2 REGIONS FOR AREAM PROJECTIONS



- NORAM USA and Canada
- JAPAN Japan
- AUS Australia
- NZ New Zealand
- ECOM European and Asian COMECON
- LAC Latin America and the Carribbean
- SASIA South Asia
- ESEA East & SE Asia and Oceania
- CHINA China
- WANA West Asia and North Africa
- AFR Other Africa

FIGURE 3 DISTRIBUTION OF MAJOR WASTES AND BY-PRODUCTS



construction, fertilizers, water, land development, land pool, food, services, and natural products.

The possible economic future for Australia that we focus on here is one of pursuing a policy of close economic links with its neighbours in the West Pacific. An experiment was performed in which trade biases between Australia, New Zealand, Japan and East and South East Asia fell from 1980 onwards towards the lowest values observed in the world at rates commensurate with those observed in the European Economic Community. The general picture that emerges is that Australia moves even more in the direction of being an exporter of primary products and an importer of manufactures. Discussions of the economic consequences of this trade liberalisation and other projected economic communities of countries around the rim of the Pacific basin are provided elsewhere.[6]

4. POLLUTER-PAYS PRINCIPLE: SOME EVALUATION QUESTIONS

The PPP is defined by the OECD as a "principle to encourage rational use of scarce resources and to avoid distortions in international trade and investment".[7] In reviewing the effectiveness and practice of the implementation of the PPP the OECD has recently posed a series of questions about this statement:

- Has it been proved in reality? In other words, has the PPP enhanced economic efficiency in environmental policies?
- Has it also proved to be an effective instrument to prevent distortions in international trade?
- Can the real international impact of the PPP be assessed?

Within the economic context of low rates of global economic growth and trade liberalisation in the West Pacific, an attempt is made in the following to answer these questions as they apply to Australia.

5. ENVIRONMENTAL STRESS REDUCTION: THE CASE OF COAL MINE REHABILITATION AND WASTE TREATMENT

The stresses considered here relate to the disposal of solid waste in the environment. These discharges form a self-contained set on which data are readily available. One point worth drawing attention to about the disposal of solid wastes in Australia is illustrated in Figure 3. The great majority of the population live near the coast, but as can be seen, many of the stresses associated with mining and industry are also situated in this area. The stresses and the model variables they relate to are shown in Table 1. All are related by simple coefficients apart from domestic waste which is a linear weighted function of the three components.[8]

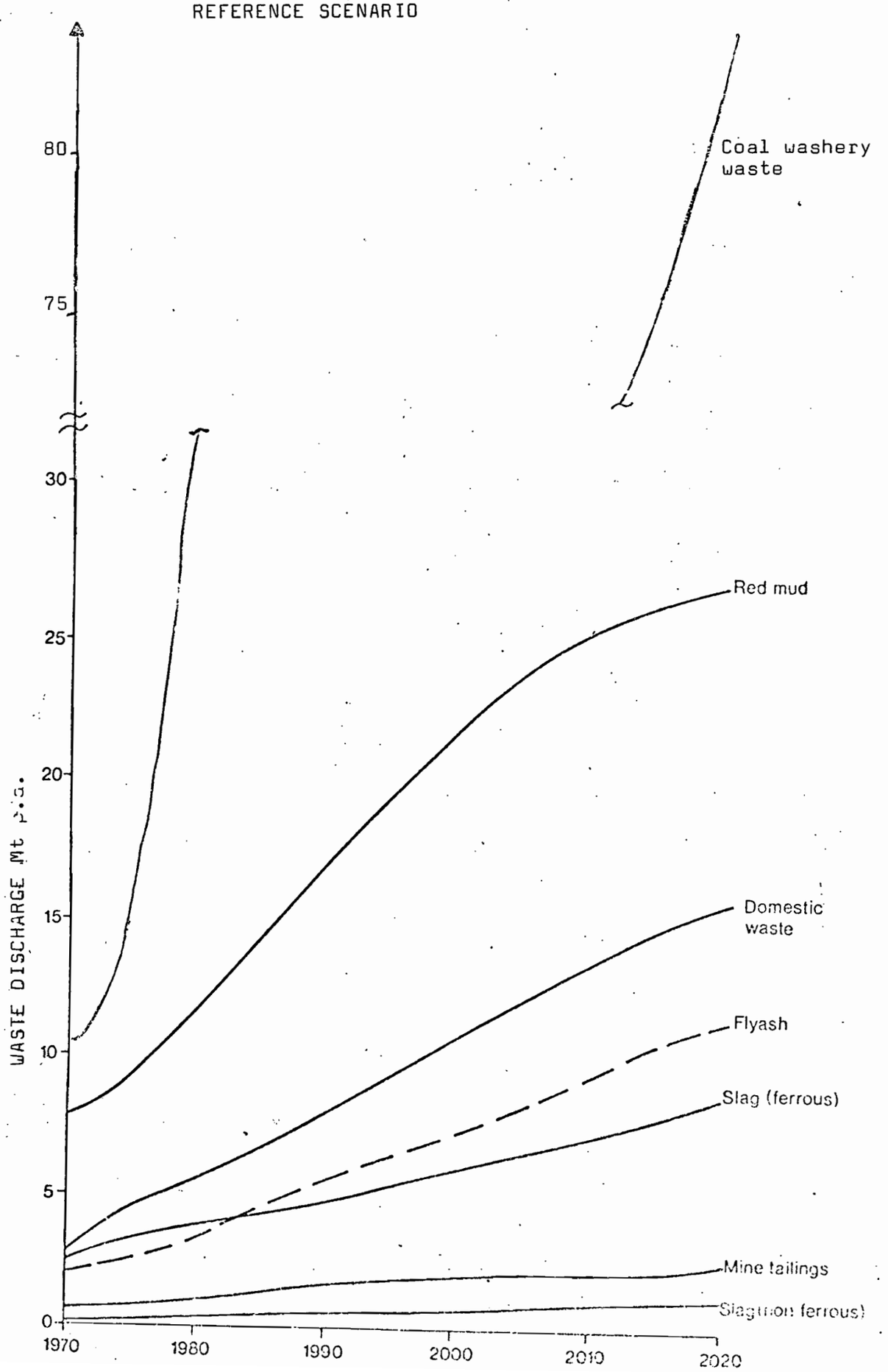
TABLE 1 STRESSES AND THE ACTIVITIES CAUSING THEM

STRESS	ACTIVITY IN AREA MODEL
1. Waste from coal washeries	Production of energy
2. Fly-ash from power stations	Consumption of energy
3. Mine tailings	Production of minerals
4. Red mud from bauxite refining	Production of minerals
5. Slag from ferrous metal production	Manufacturing production
6. Slag from non-ferrous metal production	Manufacturing production
7. Domestic waste	Final consumption of manufactures, natural products and food.

Figure 4 shows the release of solid wastes into the environment associated with the reference experiment. All coefficients have been set so as to give the correct values for waste production in 1975. The coefficients have been assumed constant, which implies an unchanging fraction recycled. The most striking result is the increase in the discharge of coal wastes. This is associated with the growth in Australia's exports of energy, mainly to Japan. The growth rate of energy production between 1970 and 2020 is 3.8 per cent per annum compared with an average for the whole economy of 2.5 per cent per annum. The growth rate in minerals production over the same period is 2.8 per cent per annum which, though not so great, still leads to very large amounts of red mud to be disposed of. The claim has been made that there is no economic way of reusing either of these two major waste products. Given the level of energy and minerals production, the figures for wastes are likely to be underestimates because of resource depletion. As more and more coal is extracted it is likely that thinner seams and lower quality coal will have to be mined, which will result in more waste per tonne of coal.

The focus in the rest of this paper is on considering the application of the PPP to the reduction of stress from coal wastes, since in the context considered here it is likely to pose the greatest problem. An experiment, however, in which aluminium production was increased tenfold, as presently projected, before the turn of the century may lead to red mud disposal and other pollution problems leading to similar or greater control costs. Two types of costs will be considered for "passing back" to the energy sector: namely, coal mine rehabilitation and coal waste treatment.

FIGURE 4 SOLID WASTES, VARIOUS SOURCES
REFERENCE SCENARIO



Overseas studies indicate a cost of $1500 per hectare for full reclamation of strip mining sites. This would add about 50 cents to the cost of a tonne of coal or 2 cents per gigajoule - an 8 per cent increase in the 1970 price of a gigajoule of energy.[10]

It has also been shown that by retrofitting fluidised-bed combustors (FBCs) to coal washery plants that a reduction of 33 per cent in the wastes is possible at a treatment cost of $1.90 per tonne.[11] Not only are these wastes reduced but they are a valuable source of low heat energy. For example, 100 million tonnes of wastes from coal mining over a given period could be processed by FBCs to yield 33 million tonnes of energy producing coal which is equivalent to 950 million gigajoules of energy.[12] The waste from FBCs can also be used as inert high-grade fill and aggregate for road making rather than just stockpiled. At present there are only pilot plants in operation in Austrlia but FBCs are being used in the USA and in Europe.[13] Another important point to bear in mind is that as a result of the greater demands being made on coal washery plants there is an increase in the volume of washery wastes and their equivalent heat value. This is borne out by the fact that in 1974-75 of the 60 million tonnes of coal washed in Australia, 15 million tonnes of wastes were stockpiled, some 25 per cent. By 1977-78 wastes had increased to 28 per cent.[14] In the following the benefits arising from the energy or by-products of FBCs are neglected and a linear relationship between the waste input and output of FBCs is assumed.

6. TRADE-OFF BETWEEN STRESS REDUCTION AND CONTROL COSTS

In the experiments that follow, the increased costs of environment protection are only applied to Australia. That is, Australian exports are placed at maximum

disadvantage relative to applications of the PPP. Thus, the costs of production simulated for a given level of protection are higher than would probably occur in practice.

The general picture that emerges in using AREAM to evaluate trade liberalisation in the West Pacific, under the conditions stated earlier, is that Australia increases its exports of primary products at the expense of greater importing of manufactured goods. The effects on the discards of coal wastes, subject to an application of the PPP to pass back the costs of coal mine rehabilitation and coal waste treatment to the energy sector, are shown in Figure 5. As a consequence of greater exports, trade liberalisation leads to an increase in the production of energy and minerals in Australia, with a consequent rise in the quantities of coal wastes. The sudden changes which occur in the coal-waste curves arise from the fact that with freer trade consumers can switch rapidly from one supplier to another as differential depletion affects relative prices.

A decline in the wastes in the latter part of the experiments mirrors a decline in total energy production. This decline was prevalent prior to the introduction of the PPP policies. One of the contributing factors to this decline is the reduced rate of Australian exports to Japan, and the emergence of China as a Japanese energy supplier. Another associated factor is the decline in the Australian manufacturing industries' demands for energy, as a great deal of these commodities are being imported. These imports are 2.6 times greater in the year 2020 for the experiments considered here when compared to the reference scenario.

FIGURE 5 WASTES FROM COAL WASHERIES

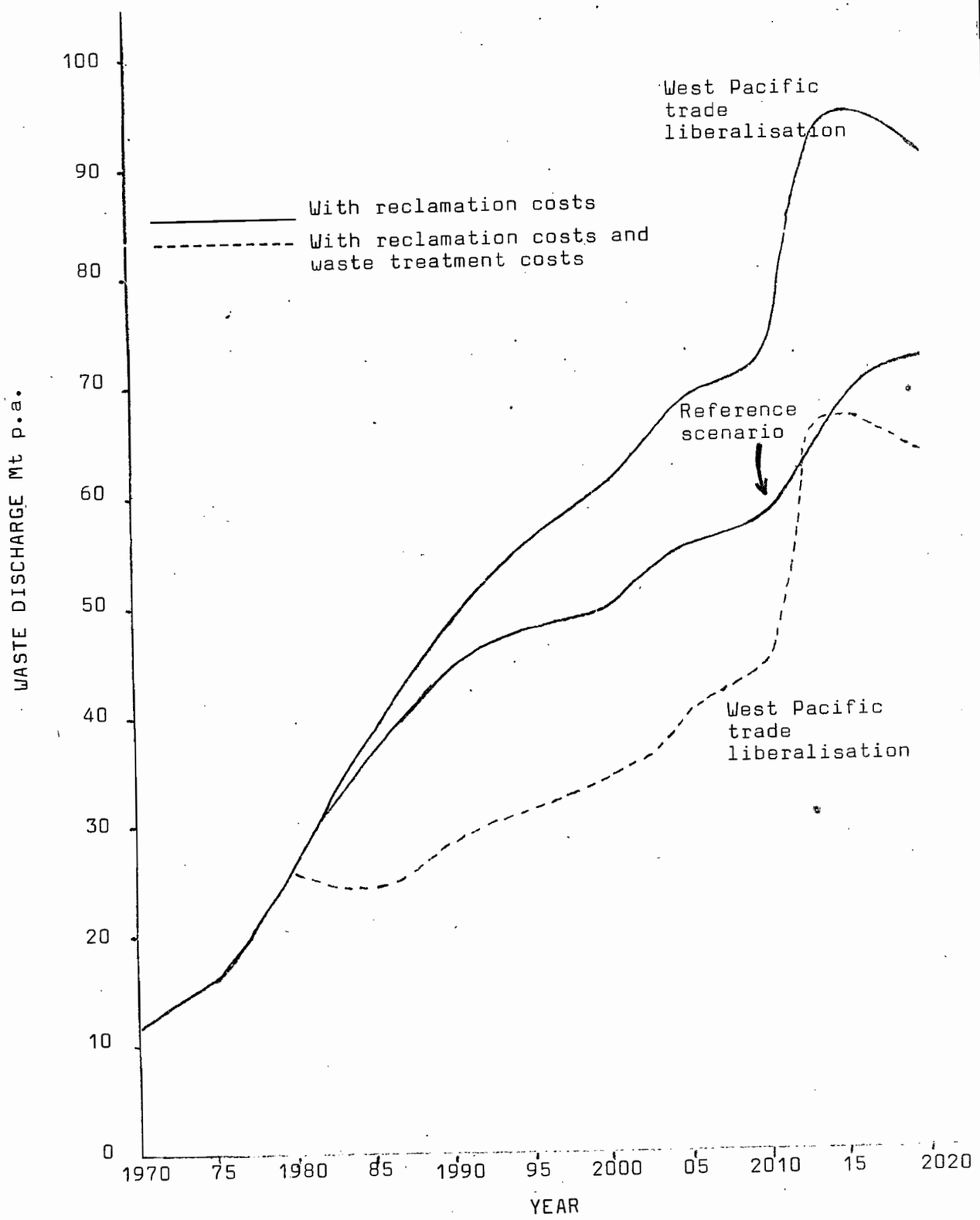


Table 2 shows the reduction in coal wastes and gross consumption per capita for the reference scenario and for the experiment of West Pacific trade liberalisation resulting from processing the wastes through FBCs and making the energy sector absorb the costs involved. The percentage reduction in coal wastes declines but remains high over the simulation period. The attendant percentage reduction in gross consumption per capita remains small over the period. The liberalised trade scenario benefits Australia in gross consumption per person (24 per cent higher in 2020 than the reference experiment if the PPP is not applied, otherwise 23 per cent), but at the expense of greater environmental degradation associated with coal mining. However, because the imports of manufactures increase, environmental stresses associated with industrial production are reduced.

TABLE 2 TRADE-OFF: COAL WASTE v GROSS CONSUMPTION PER CAPITA

CASE	YEAR	COAL WASTES/CAPITA (TONNES/PERSON/YEAR)			GROSS CONSUMP/CAPITA ($/PERSON/YEAR)			POPULATION
		No PPP	PPP	(%) DROP	No PPP	PPP	(%) DROP	(M)
REFERENCE	1980	1.75	1.75	-	4224	4224	-	14.6
	1990	2.72	1.55	43	5176	5142	1	16.2
	2000	2.71	1.46	46	6016	5906	2	18.0
	2010	3.17	1.81	44	6870	6690	3	19.8
	2020	3.51	2.17	38	7681	7526	2	20.7
WEST PACIFIC	1990	3.00	1.72	43	5246	5209	1	16.2
	2000	3.35	1.85	45	6382	6256	2	18.0
	2010	3.63	2.21	39	7692	7473	3	19.8
	2020	4.44	3.09	30	9016	8892	1	20.7

The PPP has been applied here to maximize its adverse effect on Australia's international trade; that is, the PPP has only been applied in Australia and not in the other eleven regions shown in Figure 2. Figure 6 shows how passing back the costs to the energy sector of coal mine strip rehabilitation or reclamation and coal waste treatment by the FBC process influences the total exports of energy from Australia in the reference scenario and for the experiment in West Pacific trade liberalisation. While in both cases the exports are lowered by these increases in costs for the reference scenario, the losses in the liberalisation experiment are converted after about 25 years to significant gains. These gains post-2010 are a result of a higher grade of coal being mined at an economic cost, in Australia, when all other suppliers who filled the gap that Australia left, are mining lower grade ores which are consequently more expensive to process. In effect increased costs associated with PPP policies produce a decline in exports of energy in the period to 2010. This in essence means that the energy reserves are not depleted as fast as they may have been if the policies were not introduced. On the other hand, other suppliers filling the gap that Australia would leave, are in fact depleting their resources faster than when Australia was supplying the market. Consequently, there comes a point in the experiment (around the year 2010) when the other supplier's prices are equal to and then greater than the Australian price (including exchange rate variations). From this point on, not only is the price competitive but the Australian energy exporter is also obtaining a higher price (by some 20 per cent) than they did prior to the introduction of the PPP policies, the costs of which are past on to the consumer.

The effects on sales of manufactures in Australia for both experiments each subject to the same three scales of environment protection costs are shown in Figures 7 and 8. In each case we see that increased spending on environment protection yields increases in the sales of manufactures; that is, increases in the

FIGURE 6 EXPORTS OF ENERGY-AUSTRALIA

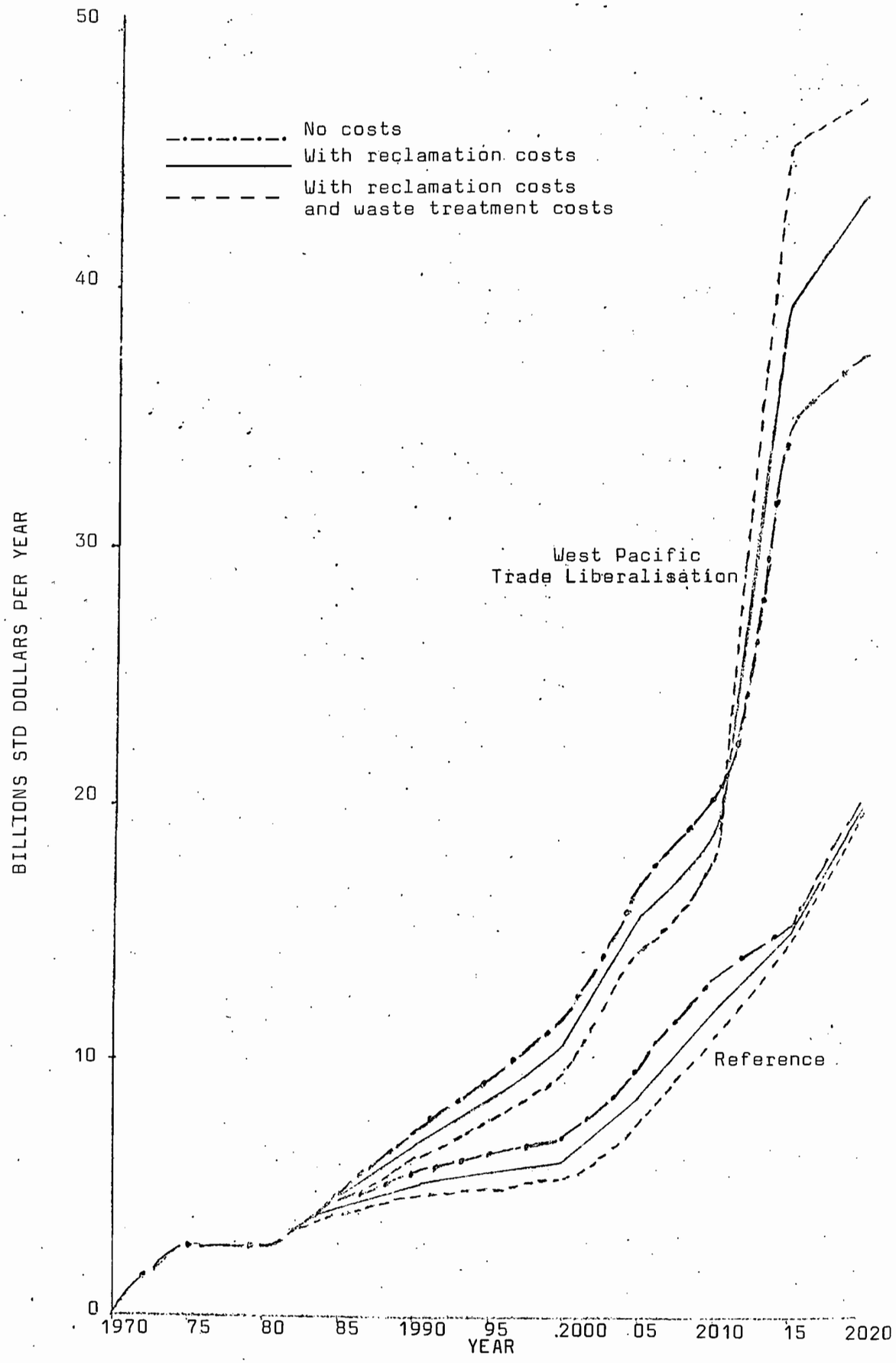
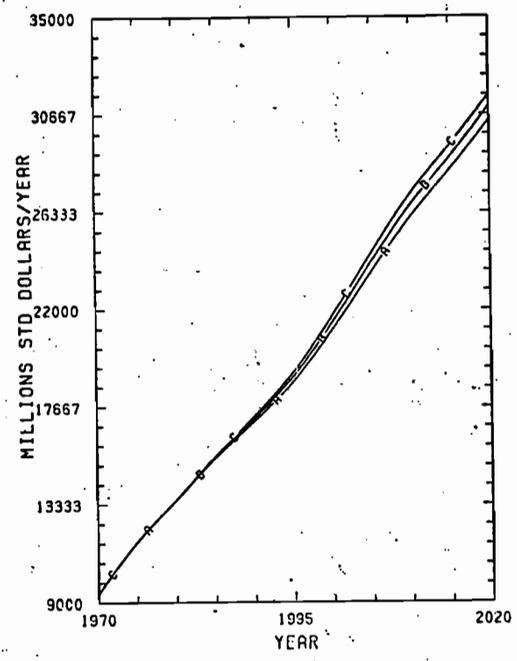
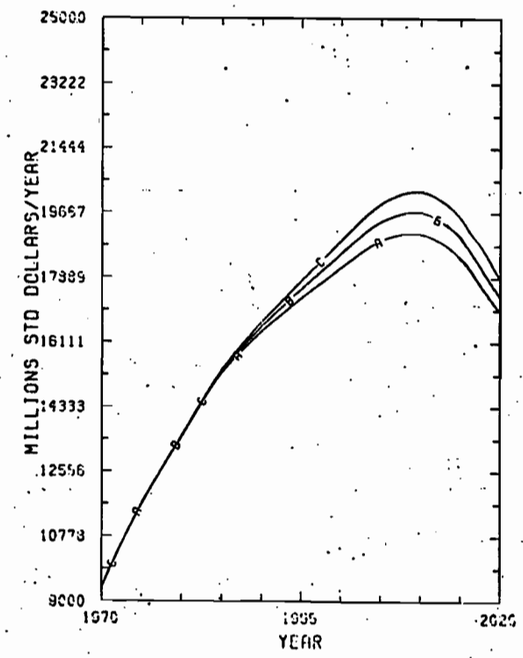


FIGURE 7 SALES OF MANUFACTURES - AUSTRALIA, FOR THE REFERENCE SCENARIO



A - No costs
B - With reclamation costs
C - With reclamation costs and waste treatment costs.

FIGURE 8 SALES OF MANUFACTURES - AUSTRALIA, FOR THE WEST PACIFIC TRADE LIBERALISATION



A - No costs
B - With reclamation costs
C - With reclamation costs and waste treatment costs.

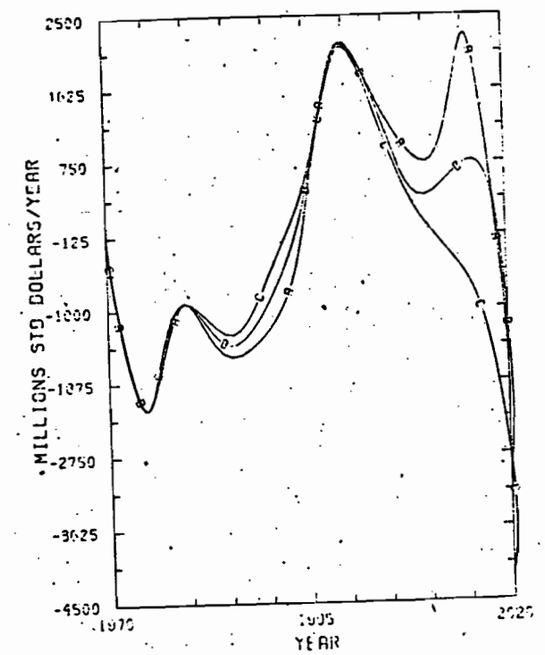
production of pollution-control equipment. The marked decrease in sales of manufactures in the trade liberalisation experiment results from the simulated shift in the structure of the Australian economy; that is, reduction in the trade biases act to make Australia a greater exporter of primary products and a importer of manufactures.

The trade deficit occurring over time for both experiments and each scale of costs are shown in Figures 9 and 10. This deficit is defined as the $ value of total imports less that for total exports of all commodities traded; thus a negative deficit occurring where exports exceed imports is a surplus. The higher the costs of environment protection the higher the deficit until the turn of the century in both experiments. The reverse is true in the ensuing ten years and in the last ten years of the simulation major surpluses are generated which are significantly greater in the cases of coal waste treatment. However, from other results not considered here, this produces its own problems as the increased wealth places pressure on the economy to import more, particularly manufactured goods. A similar situation is being experienced in the United Kingdom where the exports of North Sea oil rather than producing the surpluses expected are being offset by more imports of manufactured goods. Specifically, the decline in energy exports in the period to 2010 leads to a large deficit brought about in the main by heavy imports of manufactures. However, after 2010 the energy trade picks up and in the PPP experiments the increase is $2\frac{1}{2}$ fold in the ten years to 2020. At the same time there is only a two-third increase in manufactured imports. The figures below indicate the extent of the difference between net exports and net imports of the main traded commodities.

TABLE 3 NET EXPORTS/IMPORTS, AUSTRALIA, WEST PACIFIC TRADE LIBERALISATION (MILLIONS STD DOLLARS)

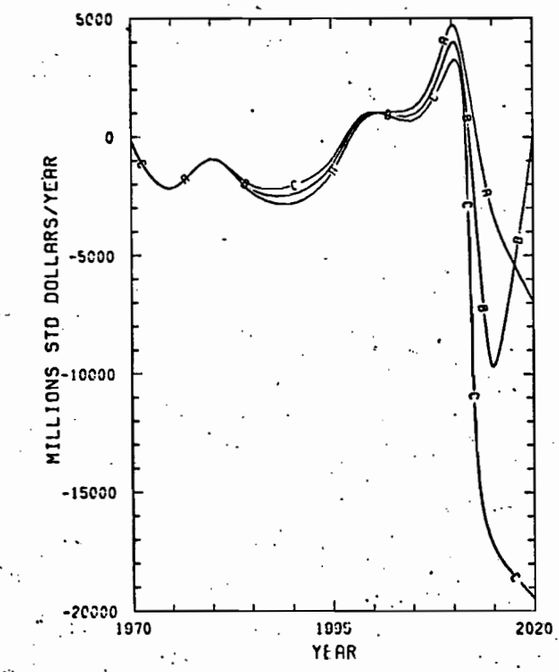
YEAR	No PPP			PPP		
	Exports	Imports	Surplus	Exports	Imports	Surplus
2010	35320	39722	-4402	33794	36684	-2890
2020	68295	60570	7725	79766	59651	20115

FIGURE 9 TRADE DEFICIT - AUSTRALIA, REFERENCE SCENARIO



A - No costs
B - With reclamation costs
C - With reclamation costs and waste treatment costs.

FIGURE 10 TRADE DEFICIT - AUSTRALIA, WEST PACIFIC TRADE LIBERALISATION



A - No costs
B - With reclamation costs
C - With reclamation costs and waste treatment costs.

7. EMPLOYMENT IMPLICATIONS

Other experiments reported elsewhere considered the employment implications of a number of economic communities comprising different groupings of Pacific basin countries and regions.[15] The effect on the labour situation by imposing the foregoing costs of reclamation and waste treatment on the energy sector are shown in Table 4 for both experiments. Increases in the labour

TABLE 4 EFFECT ON LABOUR FORCE OF POLLUTER-PAYS PRINCIPLE APPLIED TO THE ENERGY SECTOR (in millions of man-years per year)

YEAR	REFERENCE		WEST PACIFIC	
	No PPP	PPP	No PPP	PPP
1970	5.22	-	5.22	-
2000	7.66	7.65	7.69	8.39
2020	8.88	8.90	8.80	8.83

force as a result of applying the PPP are caused by the demand created in other sectors of the economy to supply the necessary equipment, materials and manpower required to affect the increased level of environment protection. In using AREAM in this case the assumption is made that the manufacturing sector supplies the added requirements and in turn passes on its own requirements to the other sectors in the model. The increased demands on the manufacturing sector shown in Table 5 produce increased demands from all the other sectors, resulting in an overall increase in the level of economic activity, even though the energy sector generates less exports in the PPP case until 2010. This loss of sales by the energy sector does not lead to a significant reduction in the total labour force. However, in the more labour-intensive sectors dealing with manufactures, machinery and construction, any increase in activity

TABLE 5 EFFECT OF POLLUTER-PAYS PRINCIPLE ON SALES OF MANUFACTURES (in million of 1970 dollars)

YEAR	REFERENCE		WEST PACIFIC	
	No PPP	PPP	No PPP	PPP
2000	21064	21696	18175	18910
2020	30380	31503	17823	18757

may have significant effects on the total labour force. In a possible future of a relative decrease in the level of manufacturing, such increases would be welcome.

8. RESPONSES TO EVALUATION QUESTIONS ON THE PPP

The main results of the experiments considered here is that analysis of the effectiveness of the PPP over a limited period, say less than 15 years, would lead to its rejection. Thus in response to the question of whether the PPP has been proved in reality, only time, and perhaps models like AREAM, will tell. Under conditions of trade liberalisation in the West Pacific, application of the PPP to only Australia markedly effects the pattern of its energy exports over time as shown in Figure 6. Thus, it appears that the PPP has the potential to control or influence distortions in international trade. While it would be a complex matter to assess this, clearly it is within the scope of AREAM to do so - albeit in fairly broad terms. The final question relation relating to the assessment of the real international impact of the PPP is even more complex. Once again, however, such an assessment is considered to be within the scope of AREAM. Planned further developments of AREAM should allow this to be undertaken on a more comprehensive basis than at present.

9. FURTHER DEVELOPMENTS

Only an outline of the results of the experiments considered here have been provided in this paper. Further documentation on these and related experiments will contain a full set of results dealing with, for example, economic and environmental effects by industry sector and by region. Further experiments with AREAM in its existing form will address the OECD questions on the PPP more comprehensively than considered here.

In other experiments consideration has been given to stresses which are not a direct function of economic variables. In such cases model outputs can be considered as indicators of environmental stress. Obvious examples are connected with agriculture where there is concern about such problems as the acceleration of soil erosion due to more intensive farming, the run-off of fertilizers into water courses and the increase in salination caused by irrigation. The yield per hectare and the total fertilizer and irrigation water consumed are available directly from the model and are used as indicators for the problems just mentioned.[16] In an experiment completed but not yet documented, AREAM was used to assess the effect of major droughts on the environment through the above indicators and on Australian food production and trade.

A powerful feature of the model is the way in which it can be used to assess the emergence of new sectors by postulating their existence as seed sectors; that is sectors in embryo form which can grow or be activated when the economic climate becomes favourable. This can be done for the next few decades, because the sectors coming to fruition in that time must now exist in seed form. Clearly the visualisation of future seeds is too speculative to be useful - hence an effective time horizon on modelling of about 50 years. Examples of experiments in which this feature of the model might be used abound:

single-cell protein as a substitute for forced-grain feeding of cattle; large scale coal liquefaction, oil from shale and ethanol from crops as alternatives to petroleum-based fuels;[17] electric motor vehicles and other unconventional engines as an alternative to petroleum or liquid fuel driven engines. Assessment of the environmental implications of such developments would also be within the scope of AREAM.

Planned extensions to AREAM will enhance the capacity of the model to probe the PPP questions posed by the OECD in greater detail than presently possible. This work is in progress in three main areas:

- An attempt is being made to describe, within the Australian region, the dynamics of population change endogenous to the model.[18] Once this is completed, it will be possible to examine the interaction between national policies for resource utilisation, environmental protection, migration and trade.

- Research is in progress to link AREAM with a static but detailed input-output model of the global economic system.[19] The aim is to provide a capability for detailed economic analyses at national and industry levels within regions, subject to the resource depletion constraints and other environmental considerations determined through time by AREAM.

- The processes of model validation and verification are being extended to the evaluation of the model by other modellers and policy analysts.

Taken together, the development work undertaken to date and the work currently in progress are expected to bring World-Australia environmental modelling to a stage where the models have practical use in government policy making.

10. CONCLUSIONS

Since global interdependence is expected to grow, we must frame national policies, to an ever increasing extent, relative to the forces generating global and regional policies. A case has been made here that a country, such as Australia, which plans to expand its international trading activities should account for the influence of environment policies on trade and economic development as well as the implications of economic growth for the domestic environment. In particular, the potential of the PPP to influence or exert some measure of control over the pattern of international trade was demonstrated for specific, but not unlikely, cases. It was shown that in some cases, and perhaps in general, that evaluation of environmental policies such as the PPP must proceed relative to a long-term time frame. Its evaluation on any other basis is likely to lead to rejection. That the PPP has the potential to influence employment levels, gross consumption per capita and other macro-economic aggregates reflecting the state of the economy was also apparent.

While contributing to the analysis of global issues and national policies, global models are not a substitute for more specialised national models; they are complementary, dealing in more detail with the world context of the expense of detail in the home economy. In further work in this field, as indicated, it may prove useful to take the trade flows, influenced as they are by resource depletion, from a global model and impose them exogenously

on a national model. The resulting analytical capacity to evaluate comprehensively options for matching economic and environmental futures should result in such models having practical use in government policy making.

NOTES

1. In deciding whether or not to build a "World-Australia" model from scratch or extend an existing global model, a series of general and specific criteria to evaluate the suitability of the latter were formulated. General criteria related to model size, economic basis, properties of disaggregation by region and industry sector, flexibility in handling changing trade patterns, level of critical appraisal, utilization by government and availability of documentation on mathematical basis. Specific criteria delt with the potential to extend the model to be extended in the following ways: (a) to measure stress on the environment resulting from economic development in physical as well as monetary terms; (b) to link economic variables, production functions, etc to variables and functions describing environmental stress; (c) to link energy development and environment protection relationships; (d) to link natural resource development and environment protection relationships; (e) to describe the population dynamics of a country or region endogenous to the model; and (f) to specify regions within each country identified as a global region. The model selected was developed by the Systems Analysis Research Unit of the UK Department of the Environment: SARUM Handbook (London, 1978) and SARUM 76: Global Modelling Project (London; HMSO, 1977). Its application by the OECD's Interfutures Project is described in Facing the Future: Mastering the Probable and Managing the Unpredictable (Paris, OECD, 1979).

2. This classification of stress-response is fully developed in D. Rapport and A. Friend, Towards a Comprehensive Framework for Environmental Statistics: A Stress-Response Approach (Ottawa, Statistics Canada, 1979). A modification of this classification to provide a proposed framework for a system of statistics on the changing state of the Australian environment is described in a forthcoming overview report on the Australian Environmental Statistics Project (AESOP), Department of Science and the Environment.

3. See D.W. Pearce, Environmental Economics (London, Longman, 1976); and P. Victor, Pollution: Economy and Environment (London, Allen and Unwin, 1972). Further detail on the approach used to develop the "environment sector" of AREAM is given in J.M. Mula, Conceptual Basis for and Environment Sector of a World-Australia Model, Environmental Studies Paper, AREA-3, Department of Science and the Environment, Canberra, November 1978.

4. Facing the Future, OECD op. cit.

5. K.T. Parker, Modelling Inter-regional Activity by Means of Trade Biases, Proceedings of 2nd IFAC/IFORS/IIASA International Conference on the Modelling and Control of National Economies, (Vienna, North Holland, 1977).

6. The most comprehensive sets of results are provided in Joseph M. Mula and D. MacRae, Assessing the Impact of Pacific Economic Communities on Australia and New Zealand Using AREAM, Proceedings of the National Conference "Trade: To Whose Advantage?" (Canberra, forthcoming) and Proceedings of the 7th IIASA Conference on Global Modelling (Pergamon Press, forthcoming). Also available as Environmental Studies Paper AREA-12 and 12a, Department of Science and the Environment, Canberra, September 1979.

7. The Polluter-Pays Principle (Paris, OECD, 1975).

8. J. Beretka Survey of Industrial Wastes and By-products in Australia (Melbourne, CSIRO, Division of Building Research, 1978).

9. Ibid.

10. C.G. Down and J. Stocks, Environment Impact of Mining, Department of Mineral Resources Engineering, Royal Science of Mines (London, Applied Science Publishers Ltd, 1977).

11. P.L. Waters, Fluidised Combustion of Coal Washing Waste, Colliery Guardian Coal International, January 1979

12. Beretka, op.cit.

13. La Na ze, Fluidised Bed Combustion - A State-of-the-Art Review, Chemical Engineering in Australia, Vol Ch.E 4 No. 4, p64, December 1979

14. G.J. Duffy and J.W. Kable, Fluidised Bed Combustion as a Solution to the Wahery Wastes Disposal Problem, Chemical Engineering in Australia, Vol Ch.E 4 No. 4, December 1979.

15. J.M. Mula and D. MacRae, Modelling Australian International Relationships : An Approach through Dynamic Simulation Modelling, Proceedings of Futurology : A Symposium on Methodologies for Social Forecasting (Melbourne, Caulfield Institute of Technology, 1980) Also available as Environmental Studies Paper, AREA-13, Department of Science and the Environment, Canberra, November 1979.

16. For further details on these experiments see J.M. Mula and D. MacRae, A Preliminary Account of Australian Agriculture in a Global Economic Contest, The Agricultural Economics Society, Canberra, August 1979. (Also Available as AREA-10) and H. Wagstaff, Food Policies and Prospects - Insights from Globel Modelling, Food Policy, August 1979.

17. See Department of Science and the Environment, Submission to the Senate Standing Committee on National Resources, Inquiry into the Replacement of Petroleum - Based Fuels by Alternative Sources of Energy.

18. For this purpose it is proposed that ongoing demographic/economic modelling work in Australia will be drawn on. For example the work of the IMPACT Project as described in D. Sams, The Demographic Core of the Impact Project : An Overview, Preliminary Working Paper No. BP-18, Melbourne, September 1979.

19. The input/output model under consideration for this purpose is under development at a number of universities in Japan. The latest documentation on the model is in Y. Kaya, The Future of Global Interdependence. A Report on Project FUGI, Proceedings of the 5th IIASA Conference (Vienna, 1977).