AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

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

PROSPECT 2000 :

AUSTRALIA IN A WORLD CONTEXT

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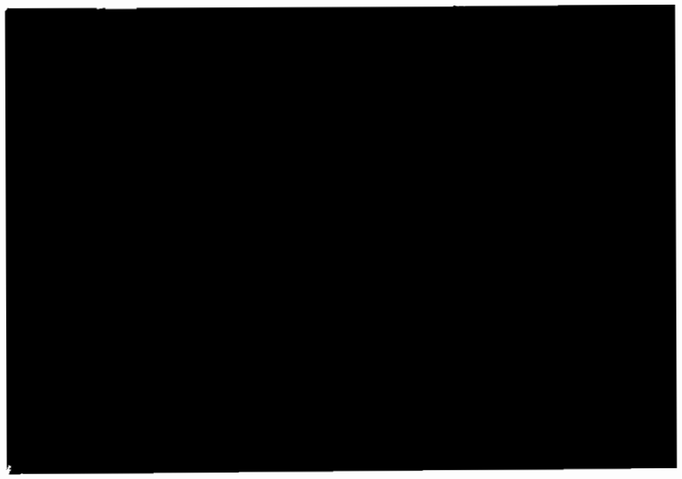
SARUM is a world econometric model developed by the System Analysis Research Unit of the UK's Department of the Environment, in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The world can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

The range of scenarios evaluated by the existing form of a model of the global economy sets the scene for planned experiments focussing on the impact of world development on the Australian environment and its natural resources. The model considers a world divided into a variable number of regions and production sectors and at present gives special emphasis to the constraints caused by the depletion of natural resources. Before turning to some preliminary results pertaining to Australia we consider briefly the national and international nature of the research network so far established in conducting this project. Preliminary results pertaining to Australia are presented. These show patterns of potential trade in food, energy and minerals between the various regions of the world and Australia. The paper concludes with perspectives on the contributions of work of this nature for policy analysis within government.

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1. INTRODUCTION

Following a brief description of an existing model of the global economy, which is being extended to assess the impact of world development on the Australian environment and its natural resources, we consider a series of scenarios already evaluated using the present twelve region form of the model. These scenarios range over the provision of adequate food for various levels of world population, the development of alternative energy sources, the response of the economic system to shocks in energy supply and directions of future trade and aid. In the first instance, planned experiments will deal with similar cases but with an emphasis on the interaction between Australia and other specified regions of the world. Subsequently these experiments will be re-run with the model extended to assess the stress of human activity, generated by the various production sectors, on the environment, in the context of the constraints to development caused by the depletion of natural resources.

The existing model referred to herein was developed by the Systems Analysis Research Unit of the UK Department of the Environment and is termed SARUM.[1] The project to extend this model for Australian Resources and Environmental Assessment has the acronym AREA- the resulting computer model is referred to as AREAM. Considerable collaboration and consultation with national and international agencies has been sought and obtained in conducting the AREA Project.

Some preliminary results generated by the existing model pertaining to Australia illustrate the nature of the first-step in this project. These results are providing a means of testing the re-run of previously evaluated scenarios with the inclusion of separate Australian and New Zealand regions in the model.

The paper concludes with perspectives on the role for modelling work of this kind within government.

2. A WORLD-AUSTRALIA MODEL

Before turning to the agenda of scenarios already evaluated and in preparation for evaluation it is necessary to say a few words about the structure of the model being developed for this purpose. First, it is a dynamic simulation model of the global economy based on neo-classical economic principles.[2]

Second, it is comprised of a variable number of world regions and economic sectors within each region.[3] Current work is dealing with the regions shown in Figure 1 and the following sectors: energy, minerals, manufactures, machinery, construction, fertilizers, water, land development, land pool, food, services, natural products. Two additional sectors will be added to this configuration. The first will provide a means of assessing the level of stress imposed on the environment by the activities of the other sectors. Since the response of the environment to these stresses will not be modelled explicitly, this sector will be *post-processing* in nature.[4] The development of the other new sector will draw on existing behavioural modelling studies[5] to describe the dynamics of demographic change in Australia internal to the Australian region of the model.

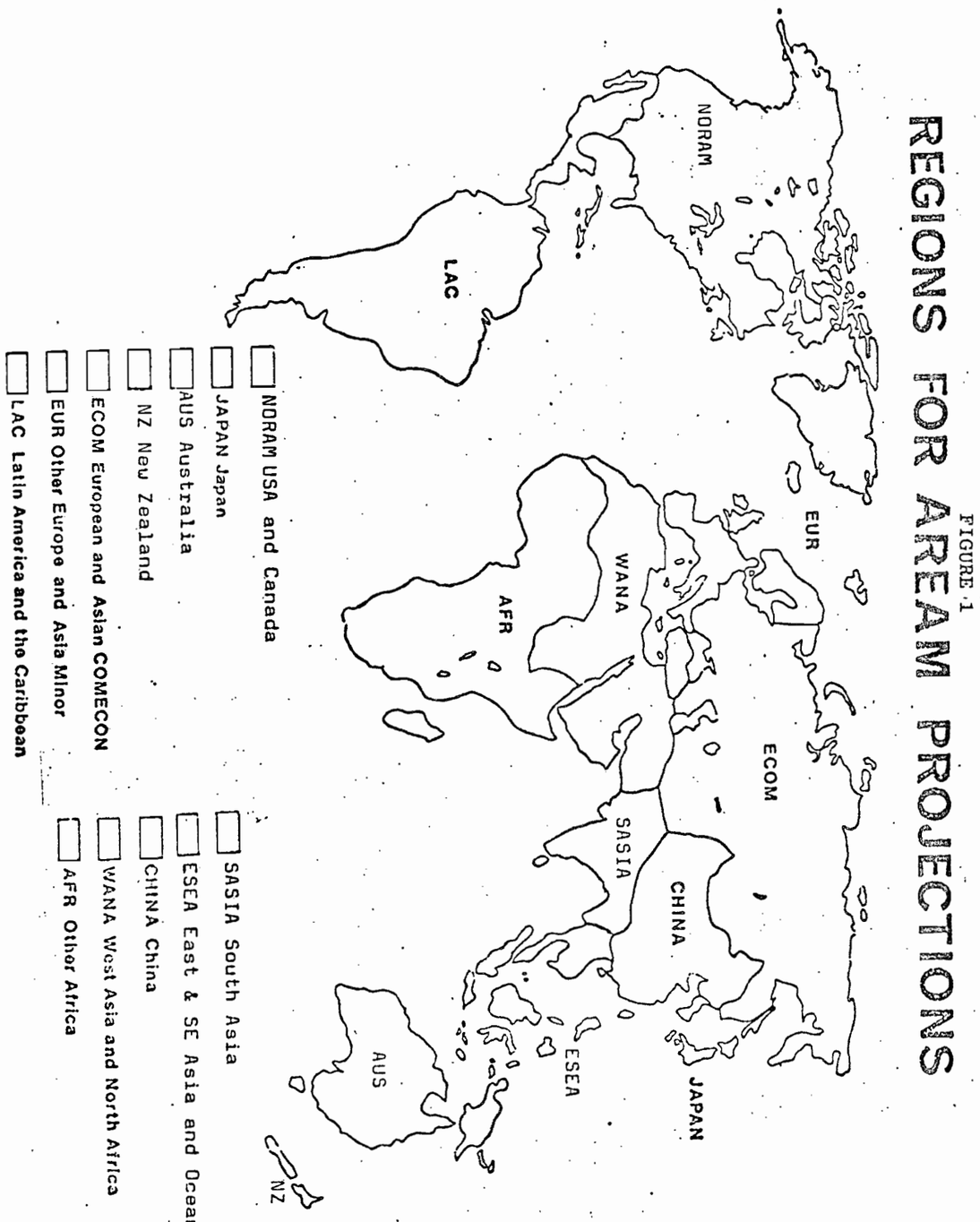


FIGURE 1
REGIONS FOR AREA PROJECTIONS

Third, by modelling the trade between the sectors of the various world regions we can address problems relating to the way regions interact with each other. In trade transactions the model accounts explicitly for factors which inhibit the functioning of a free market. This is achieved by applying a matrix of *trade biases* to each commodity traded in order to modify the prices perceived by the importer depending on the source. The bias includes the factors of economic barriers (controls and tariffs), distance, political, strategic and cultural barriers.[6] In developing a population sector internal to Australia a mechanism similar to that for applying trade biases will be examined as a means of describing the underlying flow of migration. Aid can also flow from one region to another. There is no attempt made to model the international money markets.

3. COMPLETED EXPERIMENTS

Several scenarios have already been evaluated using the existing global model. From Table 1 we can see that the clients for the evaluation of these scenarios included the UK Cabinet Office,[7] the French Senate[8] and the Interfutures Project of the OECD.[9] Results of experiments dealing with restructuring trade between developing and developed nations have been presented to an ESCAP Conference.[10] The mathematical basis of the model was subjected to the scrutiny of the annual global modelling review conducted by the International Institute of Applied Systems Analysis.[11]

Table 1 provides information on the broad purposes of these scenario evaluations. This is followed by a list of the salient features of the area of scenario investigation, the means used to activate prescribed events or activities and finally the broad conclusions of the investigations. The fifth area of investigation, conducted for the Interfutures Project, is the focus of attention in the rest of this paper.

(For further information on the other scenarios already evaluated the reader is invited to consult the references given in Table 1). Before outlining some of the broad fundings of the Interfutures Project we note here the change in the set of world regions from that shown in Figure 1. For scenarios A through E, separate regions are recognised for the EEC and other non-communist Europe while South Africa is grouped with Australia and New Zealand.

World energy demand for 1975 and projections to the year 2000 for each of the five Interfutures' scenarios A to E is shown in Figure 2. For Scenario A we see that an initial demand of 5606 million tonnes of oil equivalent grows, despite strict conservation policies, to a level of 14,622 million tonnes by the year 2000. Regional shares change over this period with a fall from 62 percent to 48 percent for the OECD countries, a fall from 24 to 21 for USSR and Eastern Europe (COMECON) and an increase from 14 to 35 for developing countries. The slower growth characterising scenarios B and C leads to lower global demands for energy of 12,449 and 13,180 million tonnes respectively. Scenario D generates the lowest level of 12,002 million tonnes in accordance with the low growth outcome of a North-South *conflict* situation. The OECD countries total drops to 40 percent of world demand. By cutting off Western Europe and Japan from its traditional sources of energy in the American continents, we see from scenario E that all energy resource deficient countries are forced to adopt stricter conservation measures, or seek alternatives sources of energy through increases in trade with, for example, Australia, South Africa, the USSR and China to meet their energy demands.

GDP and GDP per capita for scenario A are shown in Figures 3 and 4 to increase by a factor of 4.1 and 2.6 respectively over the 30 years from 1970. The share of world GDP over this period falls from 34 percent to 21 for North America and from 20 percent to 14 for the EEC, with gains from 6 to 10 percent and 18 to 30 percent occurring for Japan and the developing nations respectively.

TABLE 1

ASPECTS OF SOME SCENARIOS ALREADY EVALUATED

AREA OF INVESTIGATION	CLIENT	PURPOSE OF EVALUATION	SHORT DESCRIPTION OF SCENARIOS	MODEL LEAVERS TO ACTIVATE SCENARIO	CONCLUSIONS
1. Provision of adequate food for global population Footnote [7]	UK Cabinet Office	Study of world trends in population, resources, food, pollution to help UK keep abrest of international futures studies	. Increase in food production depends on development of cultivatible land in LDC's to increase yields . Energy availability & cost will hamper increases in yield that can come from fertilizer application & mechanisation . Although future world protein supplies could be adequate, economic, social & political problems will lead to maldistribution . Reduction in population growth rates & development of cheap unconvential food substitutes will decrease food problem	. Changes to yield functions . Changes to capital & labour requirements . Changes to energy costs by use of alternative forms . Reduction in trade biases . Increases in aid . Changes in population growth patterns . Seed sector for single-cell protein foods . Model used had 3 world strata with 13 sectors	Growth in population produces problems of equitable distribution of food because of income disparities, energy costs for fertilizer & transport, lack of capital for land development flowing to LDC's in the form of aid
2. Development of alternative energy sources Footnote [8]	UK Cabinet Office French Senate	Determine conditions for development of alternative energy sources in different world regions	. Fossil fuels will be depleted over time . As depletion progresses, prices will rise . Alternative energy technology & costs presently available are not economic but may grow given a base industry & economically favourable climate	. Seed sector with parameters of technology & costs . Investment diverted in regions where fossil sources costly . Model used had 12 world regions with 11 sectors	With a base industry, alternative energy will emerge to replace fossil fuels when it becomes economic
3. System responses to energy shocks Footnote [10]		Determine whether model responds to induced shocks & produces results similar to observed real behaviour	. Energy cartel formed by 4 world regions similar to OPEC action in 1973	. Increase in exporting price of energy at specific point in time . Suspension of feedback mechanism whereby increased price stimulates increased investment in home production . Model used had 11 world regions with 3 sectors (primary energy, capital goods, all other production)	Reasonably similarity between model behaviour and real world
4. Directions of future trade and aid Footnote [10]	UK Cabinet Office French Senate	Determine development programme necessary for mutually beneficial economic and political relationships between AIC's and LDC's	. Trade barriers in the form of tariffs, political differences & distance cause political tension. . Aid given in the form of credits are spent on consumables rather than increases in home production capabilities	. Changes in trade biases by region & commodity that reflect an increase or decrease in trade relations . Aid credits as % on GDP of AIC's channeled to LDC's . Conditional aid given that can only be used to increase home production of machinery . Restrict imports of machinery by LDC's given aid . Model used had 12 world regions with 11 sectors	Although trade in consumables increases AIC's economies & LDC's standard of living, aid directed towards development of LDC's production of machinergy increase LDC's standard of living much greater
5. Directions for future international relations Footnote [9]	OECD - Interfutures Project	Determine economic, political and social climate necessary for optimal economic growth & increased standard of living in both North and South	A North has strong growth, mutual inter-dependence, freer trade while south negotiates its integration into world economy B International relations as above but with value changes to mutually agreed moderate growth in AIC's C International relations as above but moderate growth in AIC's as result of failure to make structural adjustment D North-South confrontation with closed AIC's club formed E North-South power groups formed with trade restricted to within these groups	. Change in trade biases by region and commodity that reflect changes in trade, political and group relationships . Selective aid credits . Changes to capital/output functions and technological growth	Provide internal economic & international political problems can be overcome, greater interdependency, freerer trade trade and integration of south into world economy will be better scenario to follow.

FIGURE 2

WORLD ENERGY DEMAND-PRESENT (1975) AND PROJECTED (2000)

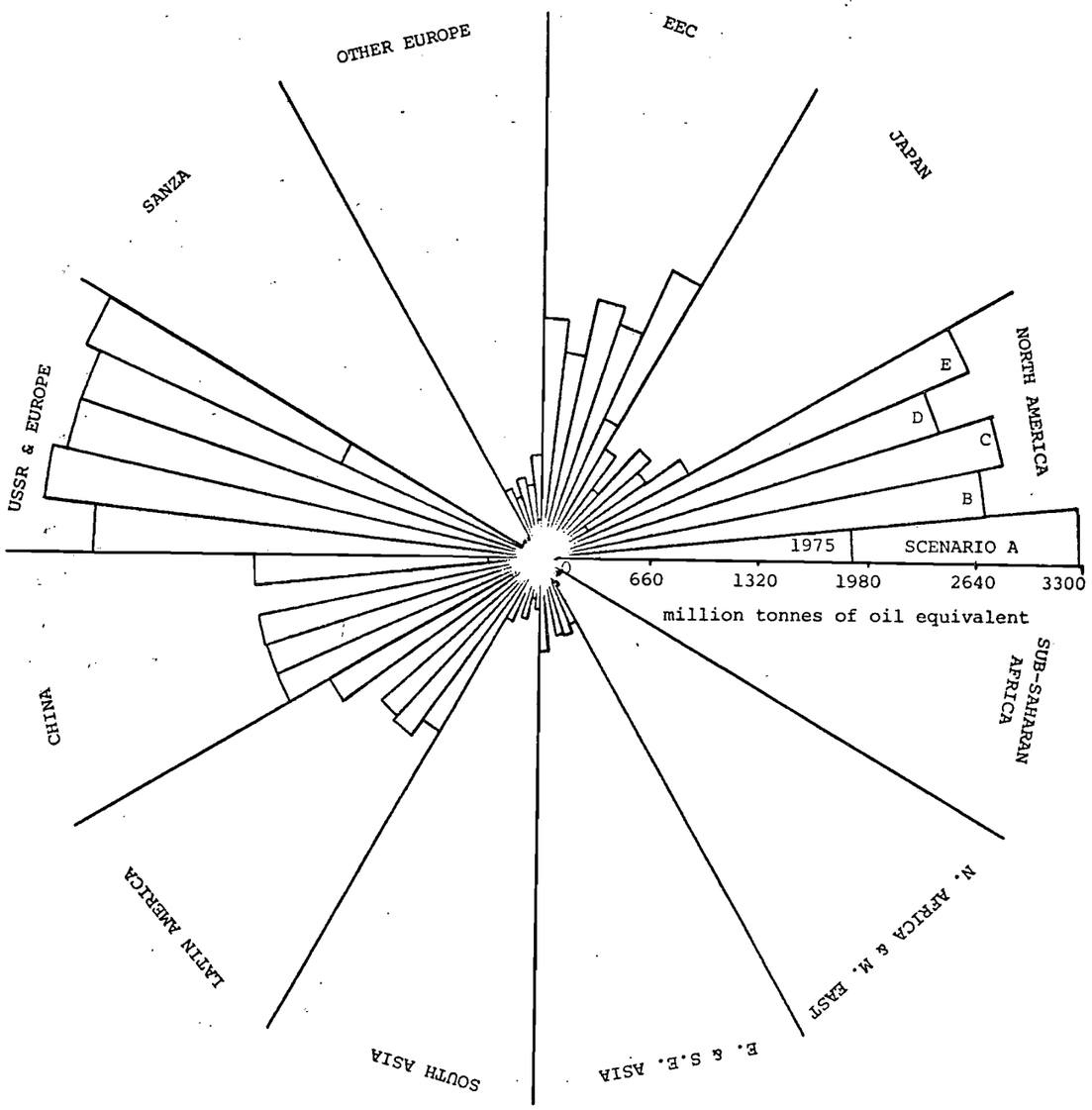


FIGURE 3

GDP PROJECTIONS FOR SCENARIOS A, C, D & E

for A : 1970 & 2000
C : 1990 & 2000
D : 2000 only
E : 1990 only

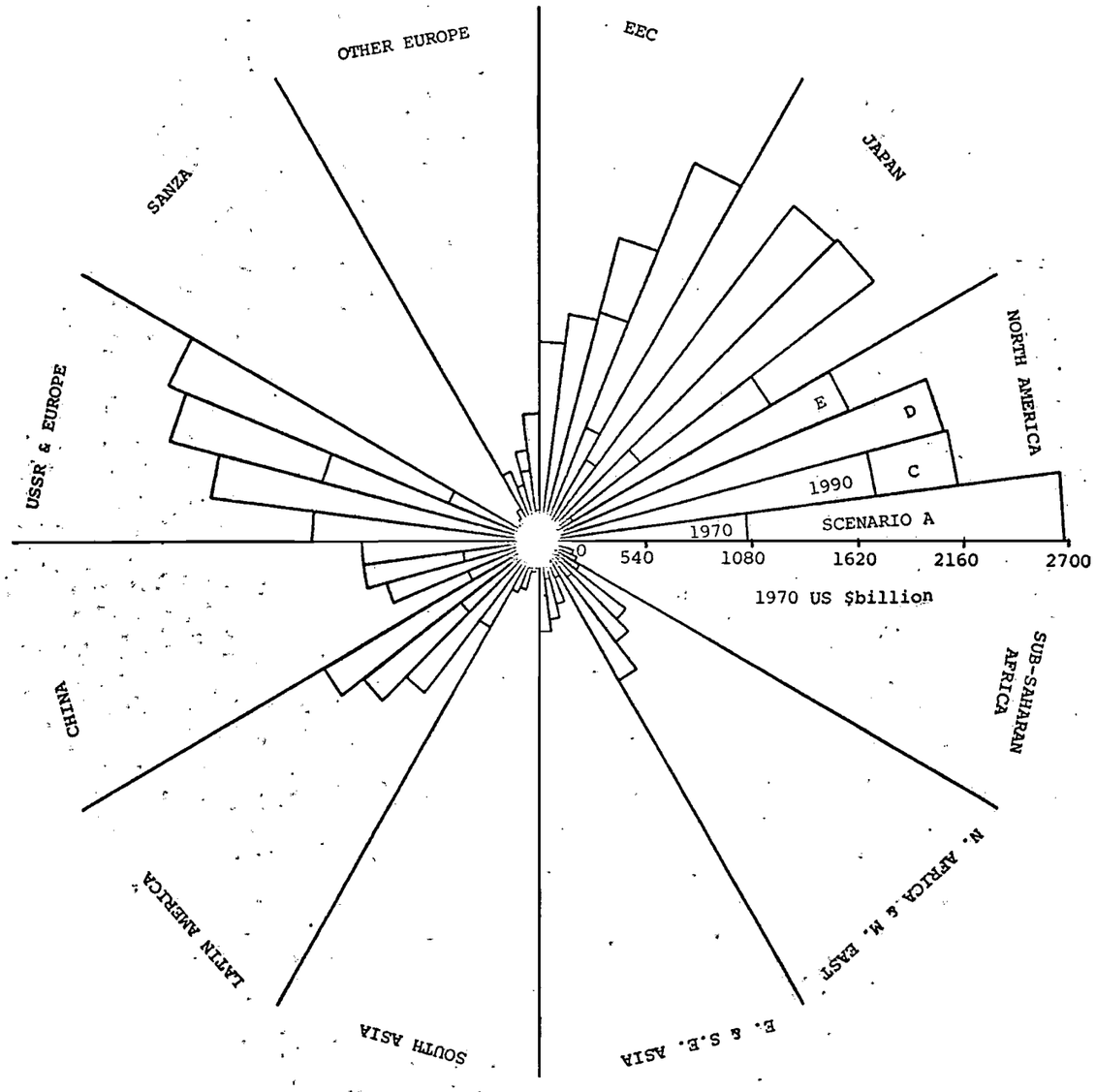
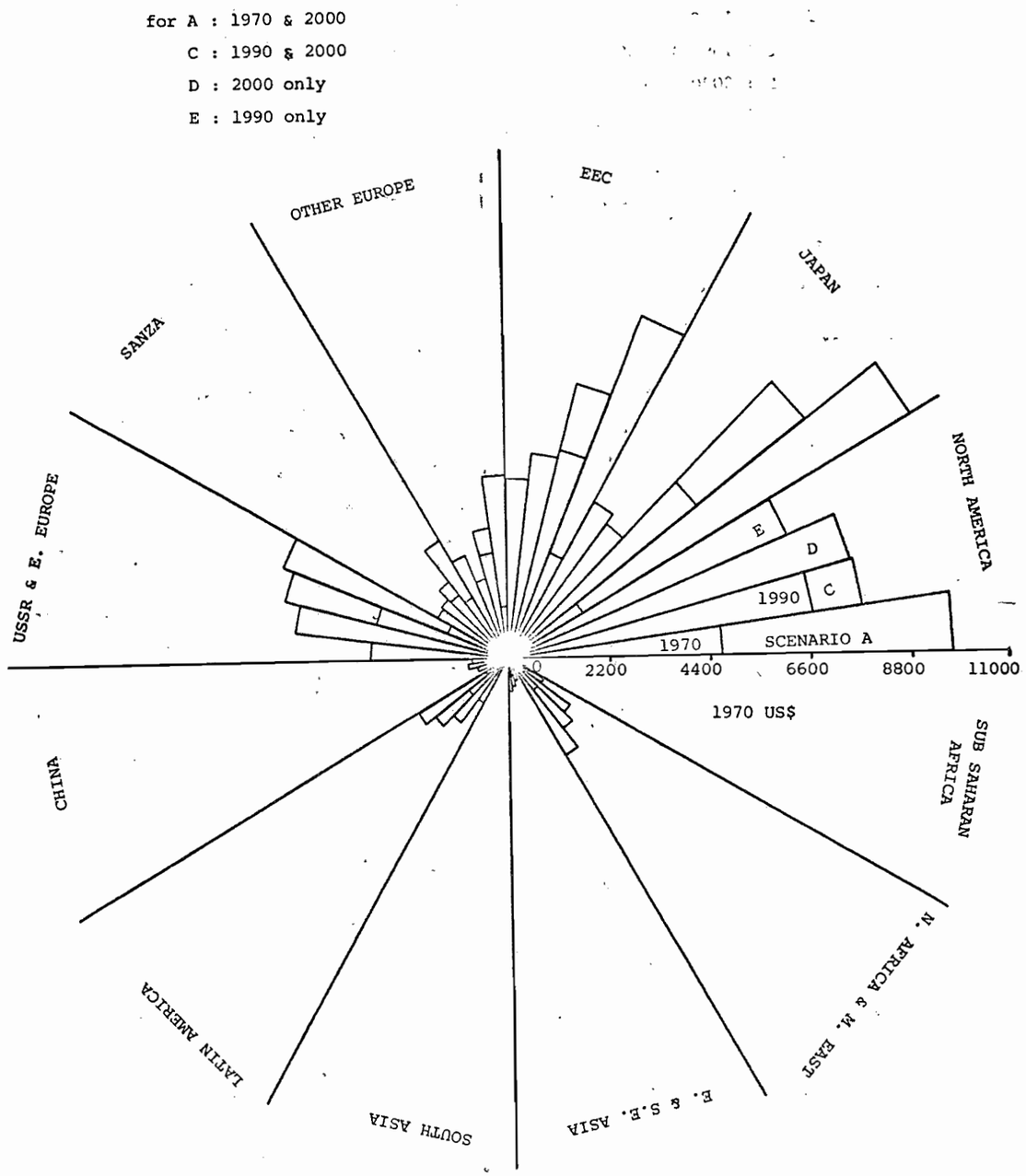


FIGURE 4
GDP/CAPITA PROJECTIONS FOR SCENARIOS A, C, D & E



Income per head over this period expressed in 1970 US dollars increases from $5000 to $10,000 for North America, from $2000 to $10,000 for Japan, from $2500 to $8000 for the EEC and $1500 to $5000 for the USSR and Eastern Europe. At the other extreme increases for sub-Saharan Africa to $400 and South Asia to $200 indicate that these regions will still be very poor. In terms of regional distribution of incomes, the present situation does not change by much: OECD countries with 20 percent of the world's population and 66 percent of the income change by the year 2000 to share 54 percent of the income among 16 percent of the global population. On the surface, the final income situation generated by scenarios B and C are very similar despite their differing impacts on the developing nations. World production increases by a factor of 2.5 and per capita incomes by 2.2 in the 30 years to 2000 for scenario C. Slight changes occur in regional shares of world production with the OECD obtaining 50 percent and the developing countries 32 percent. Per capita incomes fall symptomatic of slower growth conditions. This compares unfavourably with scenario A: scenario C yields per capita incomes of $8000 by the year 2000 for North America and Japan and levels of $6000 and $5000 for the EEC and Eastern Europe respectively.

The results of scenario D spell out the extent of economic impact produced by North-South confrontation. World production increases by a factor of 2.8 only and the per capita income by a factor of 1.8. With repercussions varying from region to region. Within the OECD, North America is least effected with its share of world income increasing to 24 percent in contrast to 20 and 21 percent levels in scenarios C and A respectively, even though its per capita income in the year 2000 is slightly down on the 1970 level. The EEC is much harder hit with its share dropping to 13 percent for D compared with 14 percent for C and 16 percent for A while per capita income barely reaches $4500. Japan's share resulting from scenario D is half its levels for A and C, dropping to 5 percent with

an attendant drop in per capita income to $3600. The developing world's share of world income increases to 33 percent but per capita income declines to $640 compared to $790 in C and $860 in A. The poorer regions suffer from the reduction in economic activity and aid.

Finally we see that scenario E highlights the regional differences that occur by the formation of North-South power groups. Non-alignment policies are practiced by USSR and Eastern Europe, China, Australia, New Zealand, South Africa and the OPEC countries maintain a neutral attitude towards their oil exports. In all, the reduction in world incomes is slight and this is reflected in the per capita incomes. The regional effects are more pronounced with North America on the improve while Latin America is affected by the loss of its European and Japanese markets and by barriers to trade inside the Third World. Although Japan is seriously affected in the medium term, Japan turns its attention to South East Asia after being cut off from its European and American markets. Its access to Australia, New Zealand and OPEC countries also helps its recovery. The EEC on the other hand, is seriously affected. Markets in Africa and South Asia can not replace those it held previously in developing countries. Its income falls and there is a serious decline in per capita income which is 60 percent of that in North America. On the other hand Africa's income increase as a result of access to European markets, while those of South Asia changes slightly.

4. A SCENARIO EVALUATION AGENDA

The first item on the agenda is to re-run scenarios A through E as above with Australia and New Zealand treated as separate regions. This will be done at the expense of grouping the EEC and other non-communist Europe to form the region EUR. Just as this will provide

a baseline for policy analysis in the environment and population areas once the pre-requisite sectors have been developed so also does simple proportional adjustment of model outputs to reflect the Australian situation with respect to scenarios A through E provide a benchmark to test the results of the first agenda item. Some of these *benchmark* calculations dealing with the pattern of trade in food, energy and minerals between Australia and the other regions are discussed later.

Some aspects of the results of this first item on the agenda are shown in the second column of Table 2. Of particular interest to the AREA Project is the joint work with SARU and the Commission for the Future in New Zealand to specify new regions for Australia and New Zealand and to examine in detail the impact of scenarios A to E on the flow of trade between these two regions. In general, we see from Table 2 that while the overall extent of national and international collaboration in the AREA Project is extensive the level of participation varies greatly from agency to agency.[12]

Turning now to the issues to be analysed with the inclusion of an environment sector. The three main areas of interest deal with the state of the environment resulting from food production, energy production and pollution control policies.

Australia is situated in a part of the world in which most people suffer from poverty and often lack the food necessary for survival. At the same time Australian's are almost as concerned about the problems of overeating. Unless this situation changes markedly and attempts are made by Australia to contribute significantly to meeting the food needs of its less fortunate neighbours then the resource diplomatic consequences of trade among these countries and Australia may have a severe long run effect on the Australian economy. By the same token taking on the business of food supplier at a greatly increased level would have profound implications for the Australian economy. Using

TABLE 2

A SCENARIO AGENDA - PRINCIPAL PARTICIPANTS

AREA OF INVESTIGATION / AGENCY	INTERFUTURES SCENARIOS (see Table 2) RERUN WITH AUSTRALIAN EMPHASIS	IMPACT OF INTERFUTURES SCENARIOS ON AUSTRALIAN ENVIRONMENT	IMPACT OF INTERFUTURES SCENARIOS ON AUSTRALIAN MIGRATION & ENVIRONMENT & MIGRATION ON ENVIRONMENT
Bureau of Agricultural Economics*	. Analyse effects on agricultural trade with LDC's especially close neighbours such as Asean, China, India.	. Repeat trade runs to investigate environment factors. . Food policy - resource diplomacy, competition from large scale energy farming . Evaluation of climatic variability and change episodes.	
Dept. Immigration & Enthic Affairs*			. Evaluation of migration structure . Determination of migration policies . Analysis of run results
Industries Assistance Commission*	. Analysis of trade relationships with all trading partners . Analysis of consequential effects on industry of changes in tariffs	. Repeat trade runs to investigate environment factors	. Analysis of migration effects on population, labour force & industry
Impact Project*			. Development of demographic structure for model using aspects of behavioural modelling carried out by Impact team . Analysis of migration effects on population, labour force & industry
Dept. Science & the Environment	. Analysis of structural adjustment & technological change effects on industry	. Analysis of energy - environment interaction . Analysis resources - environment interaction . Analysis of alternative energy - environment interactions	. Repeat environment interaction runs analysing effects of changes in migration policies
Dept. Civil & Systems Engineering James Cook University		. Development of environment sector . Evaluation of energy - environment run results	
Institute of Applied Economics & Social Research University of Melbourne	. Analysis of international links between Australia & other regions		. Development of demographic & migration structure using aspects of behavioural modelling carried out by Institute . Analysis of migration effects on population, labour force & industry
Systems Analysis Research Unit Dept. of Environment, UK	. Development of new regions for Australia & New Zealand	. Development of environment sector	. Development of demographic & migration structure
Commission for the Future, New Zealand	. Development of data specifications for Australia & New Zealand . Analysis of trade relations between two regions	. Repeat trade runs	. Repeat trade runs . Analysis of migration policies between two regions
Interfutures Project OECD	. Evaluation of Interfutures framework as a member country application		
Environment Directorate OECD		. Analysis of environment interaction runs as above . Analysis of national & international implications of polluter-pays principle . Possible inputs to 1980 OECD review of New Zealand environmental policies	
Science Policy Research Unit, Univ of Sussex Statistics Canada		. Development of environment sector	
ESCAP, UN	. Analysis of trade & aid relationships with countries in ESCAP region		. Analysis of migration policies with countries in ESCAP region
East-West Centre, Hawaii		. Analysis of environment interaction runs as above	

* A series of discussions with these government bodies has resulted in an expressed willingness to provide critiques of new sector specifications, model output and possible use of model by these agencies to evaluate scenarios of direct interest to them.

the structural framework of AREAM a range of policies relating to critical food security issues might be evaluated. The effects of tariff barriers on trade among countries, in particular in the Asian-Pacific region, could be evaluated with the aim of determining if limited trade liberalisation improves both exporting and importing countries' economies and food stability. The formation of cartels or the signing of food commodity agreements can also be evaluated. Similarly the debate among agricultural economists on the use and level of world buffer stocks, might be analysed to determine whether markets can be stabilized using such buffers and at what level should they be set to produce the desired outcome. Once optimum levels of stock are imputed a system of early warning flags could be set to determine whether signals that are being monitored indicate the likelihood of excessive depletion of stocks.

In all this a major uncertainty which could be addressed is that relating to climatic perturbation.[13] In the present context climate is taken to mean the weather affecting the next and future crop seasons - the long term weather. A deterministic approach to forecasting the future climate is not possible because insufficient is known about the key relationships. However one can assign a probability to the occurrence of a departure from the long term average climate and it is this probabilistic approach which could be adopted for use in the model.

Land is a resource that Australia has in abundance. However there are a number of competitors vying for the available arable land. The urban sprawl brought on by the growth in demand for housing and services has consumed much of the best land. If we then entertain an expansion of food production this too will increase the competition. In recent years the prospect of a significant new contender has emerged - energy plantations for the production of *biofuels* of various kinds. A number of estimates have been made as to the potentially available arable land and the land requirements

of different types of fuel crops. Studies have looked at obtaining liquid fuels from eucalyptus, cassava, sugar cane, sugar beet, agricultural and timber wastes, while others such as elephant grass, kenaf, potatoes, cereal straw and algae are under investigation. Estimates made in 1973 indicated that a target of 1×10^{18} joules per annum could be supplied by growing trees and other plants specifically for conversion to liquid fuel.[14] Alternative energy sources can be evaluated using the model which takes into consideration the competition for land and other resources as well as the economic feasibility of such investments. Like food, biofuel production would be susceptible to the uncertainties of climatic variation. Besides biofuels being obtained from energy plantations a number of other alternatives can be evaluated. One such evaluation has already been carried out on solar energy using another model, in which various scenarios were run ranging from a do-nothing or *apathy* policy to a policy of all out solar energy development. The effects of an energy shock and a solar response to that shock was also evaluated.[15] These scenarios will be addressed by the new model together with scenarios relating to various combinations or mixes of conventional sources of energy and options relating to nuclear and biofuel developments.

Through the manipulation of the trade bias matrix policies can be explored as a result of international trade relationships between Australia and other regions. Effects of neutrality in a world where there is conflict may require a different energy policy to that formulated in a free market world. Not only will it effect the economy through the balance of trade but also through the necessity of finding alternatives for normally imported energy such as oil.

Changes in energy policy have a strong influence on the state of the environment. In fact most human activity whether it be through man or his industry, effects the environment. However without the integration of environment policy with economic and social policy which in turn effect policies on energy, land-use and resources, no worthwhile

anticipatory environmental policies can be formulated for the future. What makes the task of environmental management difficult is the existance of competing demands for the scarce resources available. Different sectors of a community have goals which are diverse and management implies the definition of a path through these goals that will optimise them given certain constraints. One of the first steps along this path is to attempt to reduce all of the alternatives to a common denominator so that they can be objectively traded off against each other. Any decision making will then be made with the widest set of possible options evaluated in meaningful economic terms. Concerns have been expressed about the economic implications of environment policies. Accordingly, an attempt will be made to address the long run effects of these policies on employment in the context of scenarios A through E. The effect on efficiency and production will also be assessed in relation to applications of the *polluter-pays principle* (PPP), in varying degrees, to throw some light on the issue of whether the inflationary impact of environment policies are out weighed by increases in productivity and efficiency. Further experiments will attempt to measure the effects of PPP on trade and international relations.

5. PRELIMINARY AUSTRALIAN-BASED RESULTS

In this section a range of preliminary results are presented. These deal with aspects of food, energy and minerals problems and illustrate a few of the types of results that can be obtained from the model.

In the foregoing discussion we noted the possible importance to Australia of issues relating to *food diplomacy* and security both at the national and international levels. A major problem that may have to be faced in the next 30 years is that of massive food shortages. Although experts

tell us that there will be sufficient food for world needs, the maldistribution of that food will be a vexing problem to solve. Figure 5 shows, in part the demand for food from home grown sources by various regions according to a *status quo* scenario (ie simple extrapolation of past trends by the model). The flattening off of some curves particularly EEC and Australia indicates the reaching of a food intake saturation level while in the case of Japan the flattening off is as a result of a saturation of land available. Regions like China and East and South East Asia (ESEA) continue to increase their demand. In both cases this is as a result of increased population, but in China's case it is also attributable to an increased intake per head.

Australia's response to the increase in demand in other regions is illustrated in Figure 6 by the upswing in exports. The market to which these exports are directed is shown in Figure 7. From this figure, a move away from the traditional markets of EEC (from 36 to 24 percent in the 30 years to the year 2000) and North America (from 27 to 18 percent) is evident. There is an increase in the Japanese intake from 13 to 23 percent, for Asia from 3 to 15 percent, and for the Middle East from 3 to 11 percent. The same movement away from traditional markets is seen in Figure 8, where the ESEA region is supplying Australia with 85 percent of its imports by 2000.

The next area of concern which is illustrated in this set of results is that of energy. With an ever increasing demand for energy from both home consumption and exports, Figure 9 shows production increasing ten fold over the period 1970 to 2000. Some of this increase is due to a doubling in the price per unit of energy over the same period. The change in the export market is seen in Figure 10 where there is an increasing demand from resource poor Japan. This need by Japan to import in this way forces up its unit cost of energy by a factor of five over the period and according to this scenario the Japanese would be paying more for

FIGURE 5

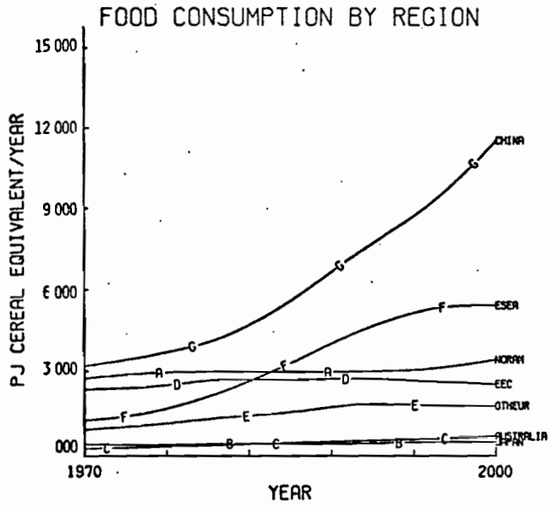


FIGURE 6

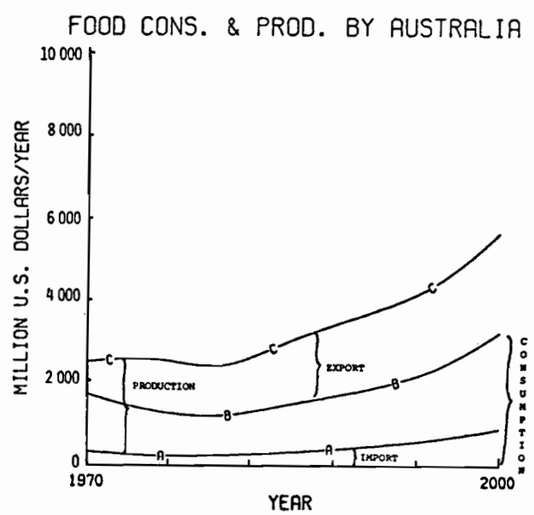


FIGURE 7

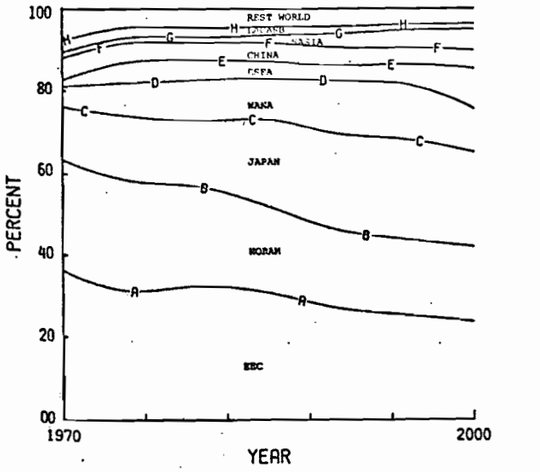


FIGURE 8

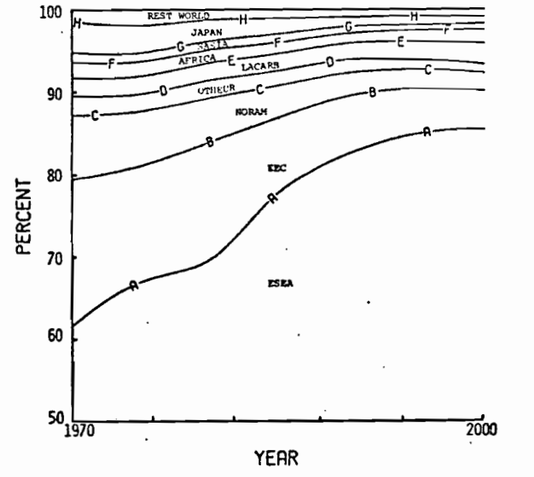


FIGURE 9

PRIM. ENERGY:CONS. & PROD. BY AUSTRALIA

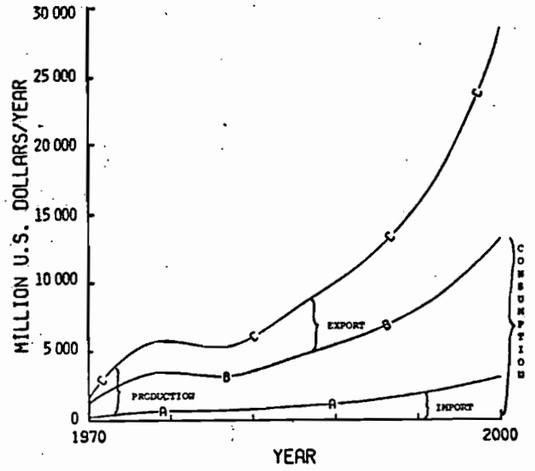


FIGURE 10

EXPORT OF PRIMARY ENERGY FROM AUSTRALIA

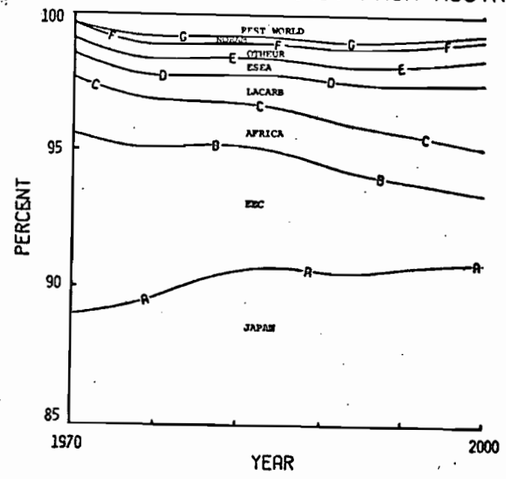


FIGURE 11

IMPORT OF PRIMARY ENERGY INTO AUSTRALIA

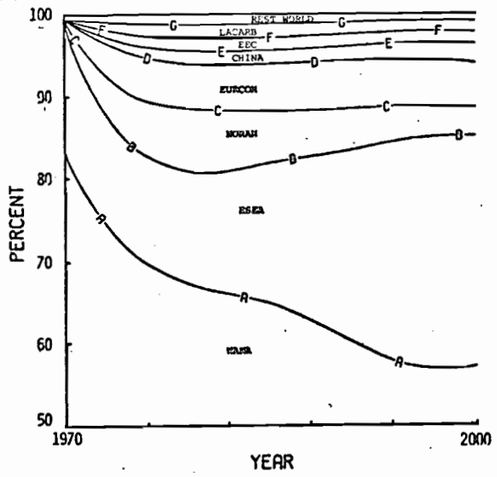
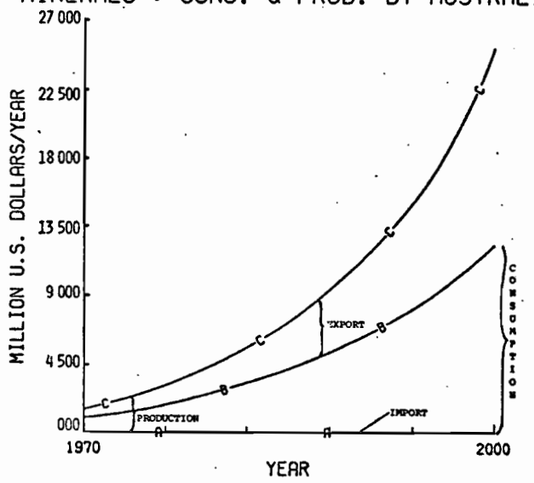


FIGURE 12

MINERALS : CONS. & PROD. BY AUSTRALIA



their energy in the year 2000 than any other region. Another change in markets is seen in Figure 11 for sources of imported energy by Australia. The drop in the share of energy imported from the Middle East is taken up in the main by South East Asia.

Turning finally to a consideration of minerals, we note for this scenario the significant growth of exports from Australia shown in Figure 12. This is illustrated by the fact that while exports are 37 percent of production in 1970 they will grow to 51 percent by the year 2000. Some of this growth is attributable to the increase in price by a factor of 2.5 over that period. Again, Japan, with a lack of resources, pays heavily for imported minerals due to a four fold increase in unit cost.

6. CONCLUSIONS

In summary, we have illustrated the form of results that are possible by extending and applying an existing model of the global economy to analyse national and international issues that may govern Australia's prospects in a world context. While this project will focus on the impact of human activity on the Australian environment and the constraints caused by the depletion of natural resources, it is possible to use the model to explore a wide range of questions affecting the economic system.

Although a strong network of communication, consultation and collaboration has been established in conducting the project this is only a precursor to the level of national and international involvement that would be required to establish a project of this nature as an ongoing part of the policy making system within the Australian Government. However, it is well recognised that the barriers to such an endeavour are high : what the policy

makers know, systems analysts often ignore; and what analysts know, the policy makers have little time to learn.[16] The exploratory work described in this paper is an attempt to cross these barriers and in so doing determine whether global models have utility to assist government in the analysis of Australia's prospects in the world context.

FOOTNOTES

1. Details of this model can be found in *SARUM 76 Global Modelling Project,* Systems Analysis Research Unit, United Kingdom Departments of the Environment and Transport, HMSO, London, 1977.

2. A summary of the salient details of the model can be found in J.M. Mula and D. MacRae, "A World Model and Its Preliminary Application to Examining Patterns of Australian and New Zealand Trade in Food, Energy and Minerals", Environmental Studies Paper, AREA-4, 1979 presented to the 49th ANZAAS Congress, Auckland, January 1979. A more detailed methodological description can be found in *SARUM Handbook,* UK Departments of the Environment and Transport, Mimeograph, London, October, 1978.

3. As the model presently stands there is a constraint on the number of regions that can be modelled at anyone time, currently 12 regions. The SARU model has the EEC and other non-communist Europe as two regions with Australia grouped with New Zealand and South Africa (SANZA) as one region. For the AREA model, the EEC and other Europe will be grouped to form Europe (EUR) thus releasing a region for the separation of SANZA. Thus Australia and New Zealand will form separate regions with South Africa being incorporated into sub-Saharan Africa.

4. J.M. Mula, "Conceptual Basis for an Environment Sector for a World Australia Model", Environmental Studies Paper, AREA-3, Department of Science and the Environment, Canberra, 1979.

5. Behavioural modelling of Australian population dynamics has been carried out by two research teams. The Impact Project under the direction of Professor Alan Powell and in particular the BACHUROD Module, has been reported in a number of publications. The other team is at the Institute of Applied Economic and Social Research under the direction of Dr Peter Brain in which the population module is imbedded in the Institute Multi-Purpose (IMP) Model. A detailed publication concentrating on this module is in print.

6. SARUM Handbook, *op. cit.*

7. Cabinet Office, *Future World Trends,* HMSO London, 1976.

8. SARU internal report.

9. A final report will be published later this year on the INTERFUTURES Project by the OECD.

10. K.T. Parker and J. Raftery, "The SARUM Global Model and Its Application to Problems of Interest to Developing Countries", presented to International Conference on Systems Modelling in Developing Countries, Bangkok, May 1978.

11. P.C. Roberts *et al,* "Proceedings of the 4th IIASA Global Modelling Symposium", Laxenburg, 1976.

12. Information on a wide range of the models being developed by those communicating, consulting and collaborating with this project is available in the paper by J.M. Mula, "A Survey of World and Australian Models", Environmental Studies Paper, AREA-6, Canberra, 1979.

13. SARUM 76, *op. cit.*

14. Australian Academy of Science, *Report of the Committee on Solar Energy Research in Australia*, Report No. 17, Canberra, September 1973.

15. The scenario results are reported in J.M. Mula *et al*, *Solar Australia - Australia at the Crossroads*, Foundation for Australian Resources, Ambassador Press, Granville, 1977.

16. This theme is developed comprehensively in the article by J. Lesourne, "Systems Analysis and International Organizations", *Ecological Modelling*, 2, 1976, pp 295-302.