AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

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

A WORLD MODEL AND ITS PRELIMINARY APPLICATION TO EXAMINING PATTERNS OF AUSTRALIAN AND NEW ZEALAND TRADE IN FOOD, ENERGY AND MINERALS

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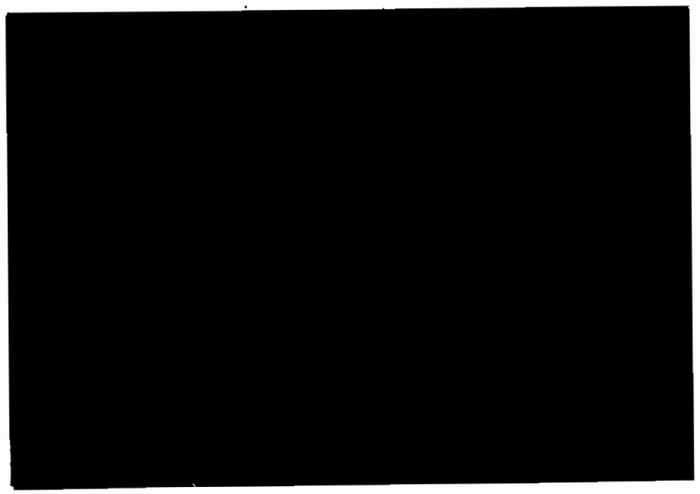
SARUM is a world econometric model developed by the System Analysis Research Unit of the UK's Department of the Environment, in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The world can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

Thanks are due to Dr Kim Parker of the Systems Analysis Research Unit for providing the trade results used here and to Dr Phung Tran for assistance in, first, adjusting these results to reflect the Australia and New Zealand trading situation and, secondly, interpreting the adjusted results.

ABSTRACT

The first step in a program of work to extend an existing model of the global economy to encompass Australia and New Zealand regions is illustrated. In this model, which gives special emphasis to the constraints caused by the depletion of natural resources, the world is divided into regions, and production into a number of sectors. A qualitative outline is provided of the model structure in its existing and its planned extended form. The results of three sets of experiments pertaining to the extended form of the model are shown. First, we address, in a preliminary way, potential patterns of trade in food between various regions of the world and Australia and New Zealand. Second, the focus is on trade in energy. Third, a brief look at trade in minerals completes the illustration of the first step to extend the existing world model. Completion of this exploratory *extension* project may lead to establishing an inter-agency project to develop and use a World-Australia model within the Australian Government.

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1. INTRODUCTION

In this paper we consider the form of and illustrate the first steps in an extension to an existing model of the global economy, which gives special emphasis to the constraints caused by the depletion of natural resources. This model was developed by the Systems Analysis Research Unit (hence the model name SARUM) of the UK Department of the Environment. The planned extensions to the model are twofold. First, to specify separate Australian and New Zealand regions, the latter in conjunction with the Commission for the Futures. In the present model those countries are grouped with South Africa in a region called SANZA. Second, to develop two sectors in addition to the eleven productions sectors currently operating in the model. The purpose of the first of these sectors will be to assess the impact of human activities, imposed through the production sectors, on the environment. The addition, also, of a population and migration sector is considered. These extensions to SARUM are being made as part of a project to explore the impact of world development and change on the Australian environment and its natural resources. The project, which is being conducted as a series of exploratory experiments in consultation with Commonwealth agencies, is referred to as the Australian Resources and Environmental Assessment (AREA) Model and the model under development is termed AREAM.

In using SARUM results to illustrate the first step in the project to develop AREAM we concentrate on patterns of trade with the SANZA region. The method of

extracting Australian and New Zealand as a separate region (ANZ) is described and the results obtained are interpreted briefly. In extracting and adjusting these figures the selection of regions and commodities as biased towards the major trade interests of the ANZ region. Thus, we consider ANZ trade in food, energy and minerals with traditional markets and developing Asian markets.

At this stage it is envisaged that successful completion of planned experiments with AREAM, dealing, for example, with the analysis of policy options governing trade and energy development, population and migration strategy, and environmental protection will be a precusor to establishing a fully collaborative inter-agency project to develop and use a World-Australia model for public policy making within the Australian Government.

2. STRUCTURE OF A WORLD-AUSTRALIA MODEL

Before proceeding to a discussion of the patterns of Australian and New Zealand trade shown by SARUM we briefly consider the structure of SARUM[1] and modifications or extensions that will characterize the AREA model. A comparison of Figures 1 and 2 show the planned regional changes to the latest experiments conducted with SARUM. Principally, Australia and New Zealand are separated from South Africa and shown as two new regions in Figure 2. The composition and number (up to 12) of regions is at the discretion of the user. The same applied to sectors, which deal with the production activities within a region. Table 1 shows that the eleven sectors currently considered in SARUM are to be increased in number to include two additional sectors in the Australian region only. The first sector to be added 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.[2] Secondly, behavioural modelling work, being undertaken by the IMPACT Project,[3] to describe demographic change in Australia is being evaluated for use in a planned population sector for the Australian region. An attempt will also be made to consider migration endogenously through use of the method for handling trade between regions in SARUM described below.

SARUM is an econometric model 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. An outling of the neo-classical principles underlying the model is given in Table 1. Model relationships are expressed by a set of first order ordinary differential equations.

$$\dot{x}_i = f_i(x_1, x_2, \ldots, x_n, u_1(t), u_2(t), \ldots u_m(t), \alpha_1, \alpha_2, \ldots \alpha_p) \quad i=1,n$$

where $\{x_i, i=1,n\}$ are the state variables, $\{u_i(t), i=1,m\}$ are exogenous variables and $\{a_i, i=1,p\}$ are the system parameters and initial conditions $x_i = x_i^0$ are fixed at time t=0. For f_i continuous this formulation can encompass higher order differential equations by including time derivatives in the set of state variables. Since the inherent inaccuracy in economic data and relationships dominates numerical effects in integrating these differential equations the simplest possible routine, Euler's method, is used with a computational interval of two months.

SARUM can also be used to throw light on problems concerning the way regions interact with each other. This is accomplished by modelling the trade between them. A novel feature of SARUM is the explicit accounting for factors which inhibit the functioning of a free market. This behaviour is modelled by defining a matrix of *trade biases* for each commodity traded which 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. Aid can also flow from one region to the other. There is no attempt made to model the international money markets.

Finally from Table 1 we see that the model is designed as a *testing bed* for policy options. There are various key policy variables that can be manipulated to explore their consequential effects. With the introduction of environment and population-migration sectors the AREA model will have an extended testing capacity as indicated in Table 1 and the description given later on planned experiments with AREAM.

The sector is the basic building block of the model. Broad interconnections between the existing eleven sectors of the model are shown in Figure 3. Focussing, for example, on the Primary Energy Sector we see that it requires inputs from the Machinery and Manufactures Sectors in addition to consuming some of its own production. Primary energy is supplied to the Minerals and Manufactures sector and some is consumed directly. By converting primary energy into electricity, petroleum products and gas the Manufactures sector operates to supply refined energy to all of the other sectors.

The internal structure of a sector is shown in Figure 4. The key state variables (rectangles) are the amounts of capital and labour used by the sector, the stock of completed goods and the fraction of the labour force trained to work in that sector. Standard economic theory underlies the relationships that are assumed to exist between variables. For example, if stocks rise prices fall. Demand depends on price and income per capita. If prices rise demand falls but if income rises demand rises. Production depends on the amount of capital and labour employed by way of a production function. The sector manager is assumed to be a cost minimiser. Given his endowment of capital he raises his labour force to the point where the

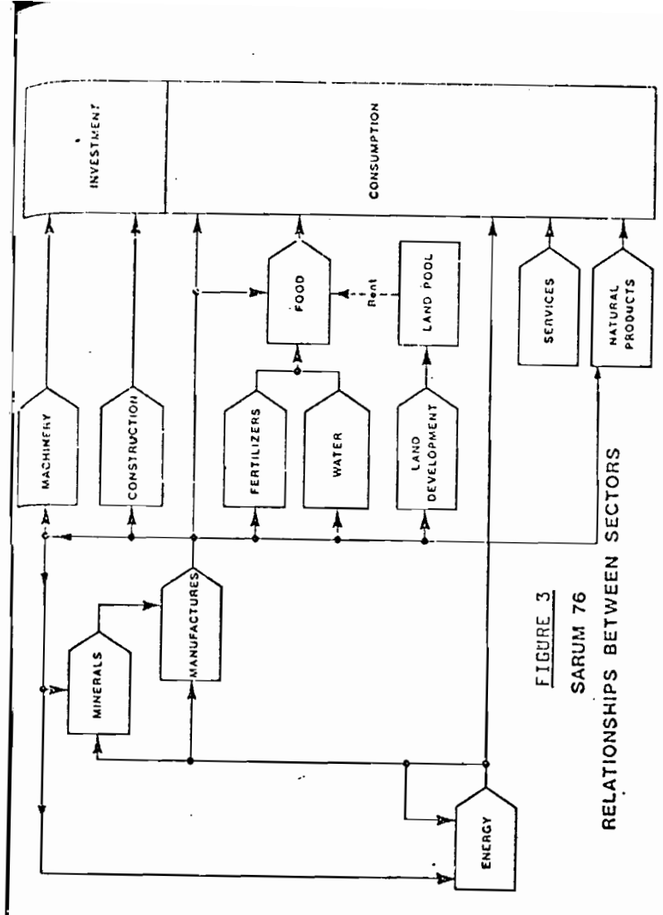


FIGURE 3
SARUM 76
RELATIONSHIPS BETWEEN SECTORS

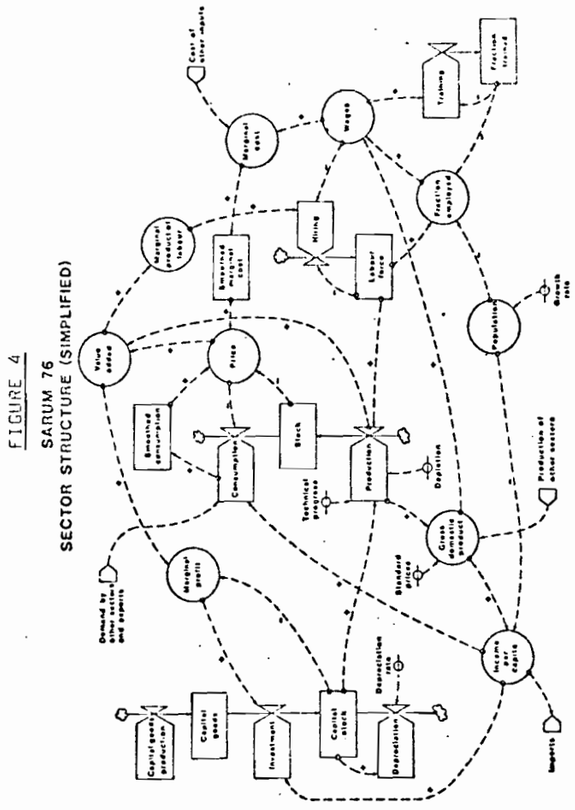


FIGURE 4
SARUM 76
SECTOR STRUCTURE (SIMPLIFIED)

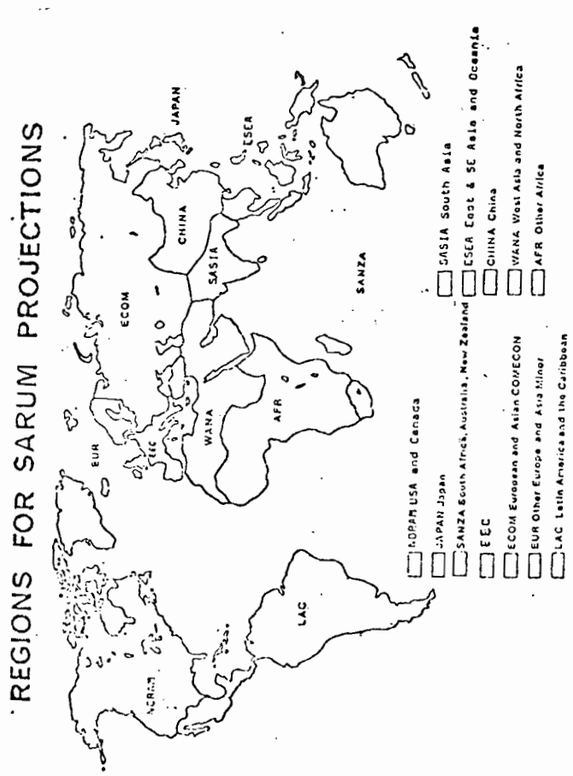


FIGURE 1
REGIONS FOR SARUM PROJECTIONS

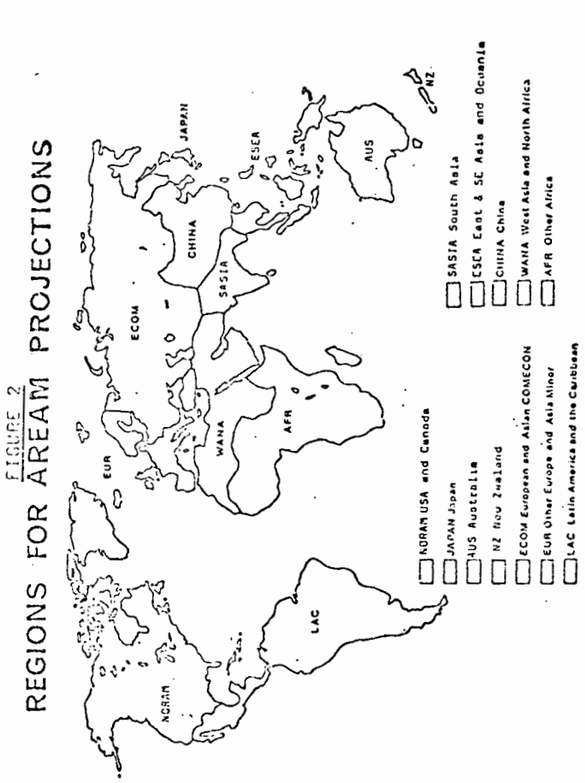


FIGURE 2
REGIONS FOR AREAM PROJECTIONS

marginal product of labour is equal to the wage rate. Quantities of intermediate products are determined by fixed input-output coefficients. Labour can move from one sector to another in response to wage differentials. The total amount of investment is related to per capita income. The fraction of this total that goes to each sector is dictated by their relative profitability. The overall effect of these relationships is to bring the size of the production sectors, after some delay, into line with the pattern of demand.

3. ADJUSTMENT OF RECENT EXPERIMENTS

The experiments described in the following have been extracted from a series of runs carried out by SARU for the OECD *INTERFUTURES* Project. In the design of the software for the SARU model programs were written whereby selected variables are dumped into a workspace on disc or magnetic tape throughout the simulation. Once these are stored they can be retrived at any time by plotting and printing routines. In retrieving the results used here attention is drawn to the fact that we have shown figures which specifically relate the Australian and New Zealand region. Throughout the discussion of these results references are made to findings which, although not set out here, have been generated by the experiments under consideration.

Before describing these experiments a number of background assumptions need to be considered. First population is assumed to grow in accordance with the United Nations' medium projection. Second, the productivity of labour and capital is assumed to converge to a common level due to the diffusion of technical knowledge to the developing countries, this level being $2\frac{1}{2}$ times the present US average after 50 years (2020). However in the area of services the productivity factor used is $1\frac{1}{2}$ times the present US figure. Third, no major changes of trade patterns

TABLE 1

Structure of SARUM and AREAM Extensions

Key Attributes	SARUM	AREAM
Geographical Regionalisation	12 Regions 1 North America 2 Japan 3 South Africa, Australia, New Zealand 4 E E C 5 European & Asian Comecon 6 Other Europe & Asia Minor 7 Latin America & Caribbean 8 South Asia 9 East & South-East Asia & Oceania 10 China 11 West Asia & North Africa 12 Other Africa	12 Regions 1 North America 2 Japan 3 New Zealand 4 Australia 5 European & Asian Comecon 6 Western Europe & Asia Minor 7 Latin America & Caribbean 8 South Asia 9 East & South-East Asia & Oceania 10 China 11 West Asia & North Africa 12 Other Africa
Regional Aggregation - Australia	11 Sectors 1 Machinery 2 Construction 3 Consumer Goods 4 Services 5 Natural Agricultural Products 6 Food 7 Arable Land 8 Irrigation 9 Agricultural Services 10 Primary Energy 11 Minerals	13 Sectors 1 Machinery 2 Construction 3 Consumable Goods 4 Services 5 Natural Agricultural Products 6 Food 7 Arable Land 8 Irrigation 9 Agricultural Services 10 Primary Energy 11 Minerals 12 Environment 13 Population
- Rest of the World	As above	12 Sectors Section 1 to 12 as above but population exogenous
Regional Interface	Trade and Aid	Trade and Aid Migration (for Australia/New Zealand only)
Methodology and Structure	The basic methodology to be used in both models is the same except that new methodology will have to be developed for the additional sectors of the environment and population as well as the additional interface of migration.	
- Economic Theory	Basically neo-classical economics such that all other things being equal: 1. Consumers will choose goods & services that maximize their utility given the price. 2. Entrepreneurs will select production techniques that maximize profit given the factor price. 3. Producers cannot affect price of goods they sell by adjusting output. 4. Producers cannot affect price of goods they buy by adjusting demand. 5. Labour & investment will flow to those industries where wages & profits are highest. 6. Prices are in inverse function of stocks. 7. A set of prices exist that will clear all markets apart from desired stocks. 8. Consumers will buy more of goods if its price falls & if their income rises unless good is 'inferior'. 9. Entrepreneurs can enter or leave any industry depending on whether they make a profit or loss.	
- Type of Functions	1. Cobb-Douglas production functions are used to determine output. 2. Depletion functions of 2 types: - resource - limited where costs of production rise with every unit produced; - flow - limited where costs rise with rate of production.	
- State Variable	1. For each region: - Exchange rate - Smoothed GDP - Smoothed Interest rate - Smoothed growth rate of capital stocks; - Smoothed value of investment - Smoothed value of exports - Smoothed average return to land; - Total area of arable land in use. 2. For each sector within region: - Capital - Labour - fraction trained - Smoothed supply cost factor - Utilisation factor. 3. For each commodity within region: - Smoothed sales of each region's product - Fraction bought from each region by region - Stock in each region. 4. For each final demand commodity in each region - Smoothed consumption. 5. For each crop-producing sector in each region: - Fraction of total arable area used for each crop; - Smoothed fertilizer use - Smoothed irrigation. 6. For each resource limited sector in each region - Cummulative production. 7. For each substitution in each region - Smoothed relative price.	
- Trade & Bias Matrix	1. Trade sector models the following features of the economic system: - Countries can draw supplies from a number of services even though significant price differentials exist; - Countries may import & export the same product; - World trade patterns react sluggishly to changes in relative prices; - Trade is used by some countries as an extension of strategic and diplomatic policy; - Transportation cost may be a decisive element in total cost at market. 2. Factors affecting trade such as distance, politics and tarriff barriers are summarized by a trade bias matrix. 3. Biasis, which highlight political blocs on trade, are used to modify the actual prices so that decisions to purchase are made on a perceived price and then purchased at an actual price. 4. Trading activities create surplus and deficits on countries balances of trade but through a debt erosion algorithm they pay off their deficit. 5. Deficits are not allowed to grow continually but are required to be paid off or credit is withdrawn; one way of reducing the deficit being to reduce consumption of goods and imports. 6. Biasis can be calculated for any particular good or for a standard basket of goods, at any time and are calculated from data on: - Country by country import matrix in physical or money terms; - Prices in each country; - Weighting factors, eg production in each country; - Price elasticities of fractions imported by each country.	
- Policy Variables	1. Population growth patterns. 2. Growth of production in a sector as a result of technical progress. 3. Trade policy through alteration of biases. 4. Monopolistic control of price and supply. 5. Anticipatory investment. 6. Modification of consumption patterns. 7. Aid in the form of money or goods. 8. "Seed" sector methodology where if the economic climate is right the new sector will grow, eg renewable energy, hydrogen, etc.	1 - 8. As for SARUM. 9. Fertility rates. 10. Migration flows. 11. Environmental stress-response to: - agricultural activity; - industrial activity; - mining activity; - various energy forms; - demographic change.

are assumed and trade biases between the regions are assumed to be constant. Finally, the availability of the amounts of land and water are based on the best published estimates. As these resources are depleted their costs rise, this same assumption being made for energy fuels and minerals.

The experiments considered pertain to the SARU regions shown in Figure 1. In this figure South Africa, New Zealand and Australia are shown as one region. We have used figures produced for the SANZA region and by arithmetic proportions extracted out South Africa. The crude approach is only a first approximation to include South Africa with Other Africa and separate Australia and New Zealand into two separate regions. The proportions used for this dissection of SANZA are shown below:

TABLE 2

PROPORTIONS USED TO EXTRACT SOUTH AFRICA FROM SANZA

		SA	NZ	AUS
Food	- Exports & Consumption	25	21	54
	- Imports	29	10	61
Primary Energy	- Exports	48	0	52
	- Consumption	48	2	50
	- Imports	29	10	61
Minerals	- Exports & Consumption	22	0	78
	- Imports	29	10	61

Note: Consumption refers to the consumption of the locally produced commodity.

4. A SIMULATION OF TRADE IN FOOD

When all types of food commodity are encompassed in a single sector for modelling purposes, a major requirement is to ensure that the different demands placed on land

resources by different diet patterns are reflected in the measurement of output. In the present food sector, the relative weights attached to the various commodity groups are based on the amount of arable land they are estimated to require for gigagoule (GJs) of food energy available to the household, compared with the amount of land required to supply 1 GJ of food energy from cereals. The relative weights for broad commodity groups adopted here are: cereals 1.0; sugar and fats 0.53; fruit and vegetables 1.54; livestock 5.0. The other problem encountered is that some 50 per cent of the world's total livestock food energy is met from grassland and waste products. The problem has been approached by calculating the amount of arable land that would have been required to produce the equivalent amount of livestock feed in the form of cereals and adding this *arable equivalent of grassland* to the actual arable areas of each region. Food does not include tea, coffee cocoa, tobacco, natural fibres and leather. rubber, timber and other forrest product and fish.

In order to explore export markets for food from Australia and New Zealand (ANZ) we might start by projecting, as shown in Figure 5, the consumption of food produced locally in the world regions most likely to trade significantly with ANZ in this commodity. These figures show, in part, the demand for food, While developed regions such as ANZ and the EEC are rapidly reaching a saturation level of 1.3 gigajoules per head per annum the developing regions are shown to increase their consumption of food from home grown sources by a factor of four. This indicates a potential for ANZ food exports beyond, or partly in place of, those to the more traditional markets in Europe and North America. By inspection of UN population projections we see that China, with a 50 per cent increase in population over the period 1970-2000, is expected to increase its food intake per head much more rapidly than the East and South East Asia (ESEA) region which is expected to double its population in the same period. Japan with a 20 per cent increase will have

a decline in intake per head caused by its limited land resources. From the full set of results of this experiment it was seen that Japan will rely more heavily on imports of food and will tend to substitute cereals for meat.

To what extent can Australia and New Zealand extend their production with the aim of increasing their food exports? From Figure 6 we see production is approximately halved between domestic consumption and exports and imports, as a percentage of total consumption, remain fairly constant. Thus it would appear that the major potential limiting resource, namely land, has not been depleted. Figure 7 shows the exports of food from ANZ by region. It indicates a definite decline in the EEC and North American markets with an increase in the share of the Japanese market (1970 - 15 per cent, 2000 - 25 per cent). The ESEA market increases particularly in the last 5 years. The steady China market is due mainly to the standard biases as set for 1970 and possibly do not reflect current diplomacy. With respect to the origin of food imports to ANZ. Figure 8 shows a marked swing from the EEC and North America to the ESEA region.

5. A SIMULATION OF TRADE IN ENERGY

The primary energy sector is modelled from data on the coal, oil and natural gas industries, but consumption implicitly includes allowances for nuclear and hydropower, treating them as if they were fossil fuels. The energy trade flows in money terms do not correspond with SITC 3, since the latter includes processed fuels which are treated as manufactures in the model. Energy for manufacturing includes energy for other material production sectors, these intermediate demands being felt only via the general demand of these sectors for manufacturers.

In this experiment Japan, as expected, was found to be the region least able to supply its own energy requirements internally. The ANZ region, on the other hand, is expected to increase its exports to some 60 per cent of its production (Figure 9). However, this does not reflect New Zealand's energy deficiencies nor the decline in oil production. Figure 10 represents the export markets for Australian energy, the majority bound for Japan. Again note the comment made in relation to the trade biases and the current relationships between Japan and China. It is envisaged that Australia may loose some of its potential market in Japan to China in the near future (an experiment which will be conducted in the future using AREAM). The decline in the ANZ-EEC market is shown, with an increased supply to the EEC flowing from the regions own resources and imports from other regions. Imports, particularly of oil, will have a significant impact on the ANZ region. Figure 11 shows that at present most of the ANZ imports come from the Middle East (in the WANA region) but that the 16 per cent share held by ESEA will increase to around 25 per cent by the year 2000 with the WANA share decreasing from around 83 per cent to around 57 per cent.

6. A SIMULATION OF TRADE IN MINERALS

In the minerals sector production and consumption estimates for 20 individual minerals (in physical terms) are weighted by their estimated average unit values of ore - equivalent in international trade, to give composite values for each region. These estimates are then adjusted to give consistency with net trade flows in value terms.

The dominant feature of the only projection given here, Figure 12, is the growth in mineral exports from ANZ: from 37 per cent of production in 1970 to 51 per cent by the turn of the century. Consumption through this period, expressed as a percentage of production remains fairly constant and imports remain insignificant by comparison.

7. PLANNED EXPERIMENTS

Experiments already conducted by the SARU team include the following:

(a) an evaluation of the economic conditions necessary for a *seed sector,* for example, meat production from animals fed on single-cell protein to compete with an established sector such as meat produced from grain-fed animals;[5]

(b) a very interesting attempt was made to track the behaviour of world trading patterns following the 1973 cartel action by OPEC;[6]

(c) an evaluation of the consequences of developing nations restricting the imports of manufactured goods to promote domestic production of these goods was made through an application of the trade bias matrix to reflect the required trade policy decisions;[7]

(d) manipulation of, for example, population growth estimates using UN high, medium and low projections and the movement of food consumption from meat to grain as land is depleted and its development costs rise have been conducted for the UK Cabinet Office,[8] the French Senate,[9] the OECD,[10] IIASA[11] and research groups.

The foregoing experiments with SARUM, from which select trading patterns of Australia and New Zealand were extracted, will be repeated once these countries have been incorporated as separate regions, to determine if and why differences are generated.

Once the sector for estimating levels of stresses imposed on the environment by human activities is added to the description of the Australian region an attempt will be

FIGURE 5

FOOD CONSUMPTION BY REGION

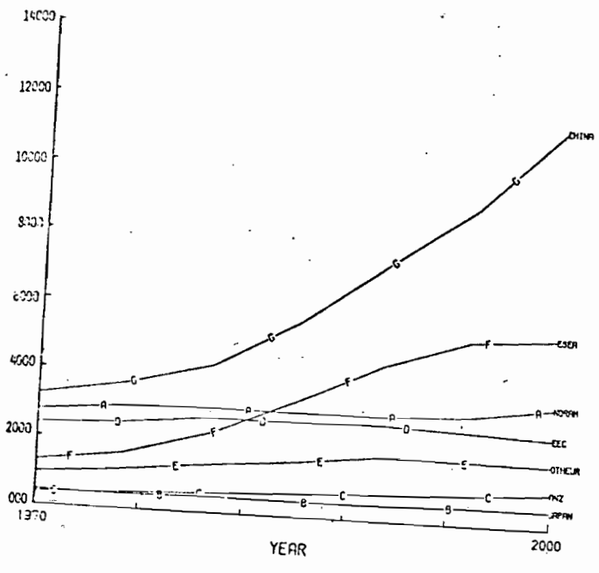


FIGURE 6

FOOD CONSUMPTION AND PRODUCTION BY ANZ

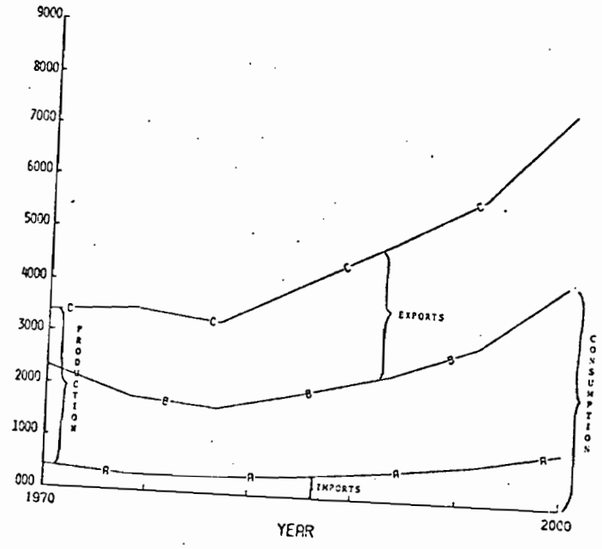


FIGURE 7

EXPORTS OF FOOD FROM ANZ BY REGION

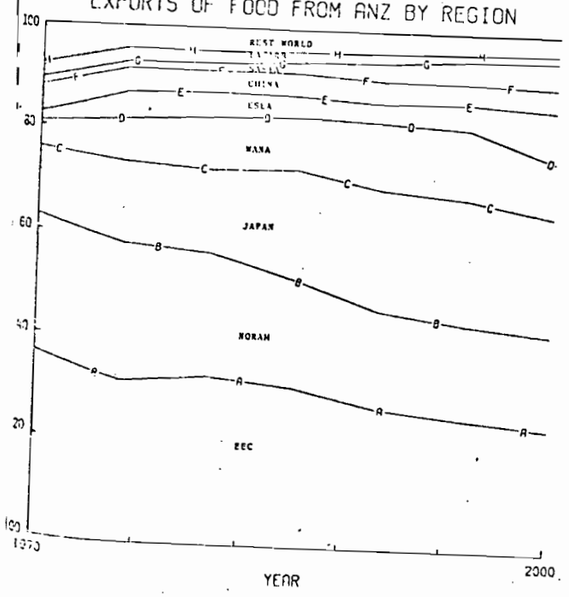


FIGURE 8

IMPORTS OF FOOD INTO ANZ BY REGION

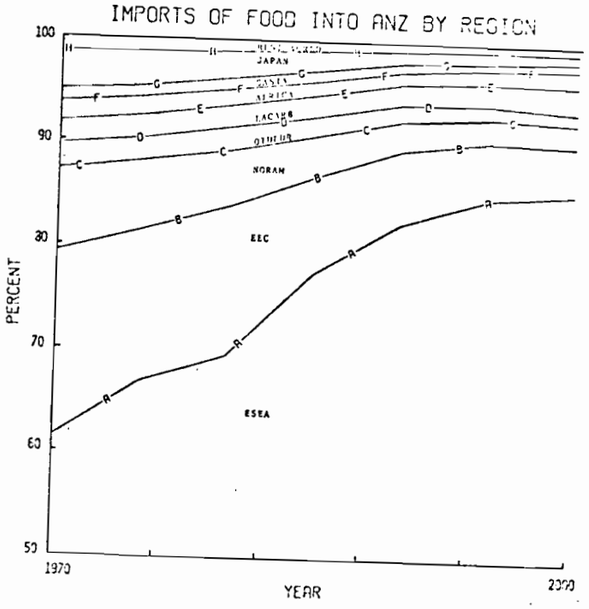


FIGURE 9

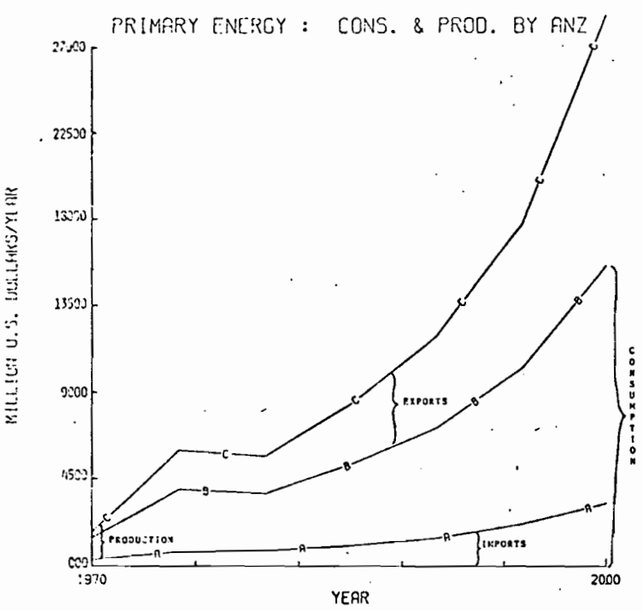


FIGURE 10

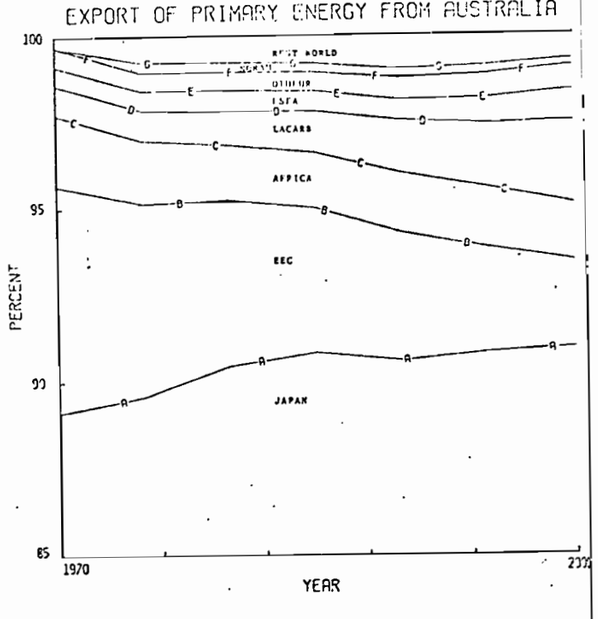


FIGURE 11

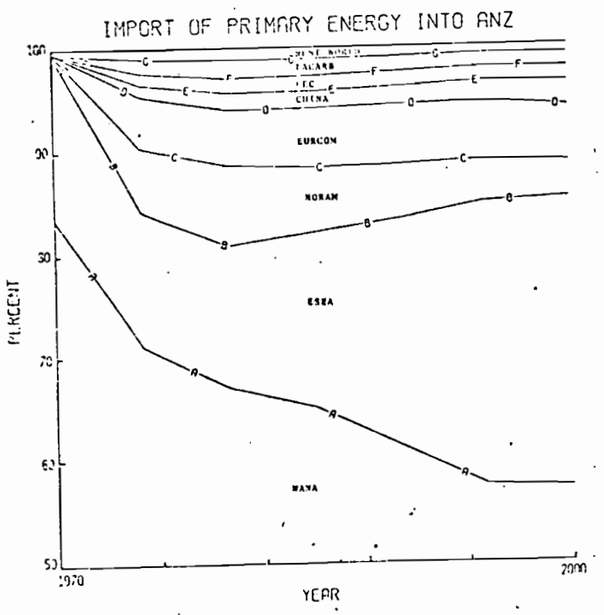
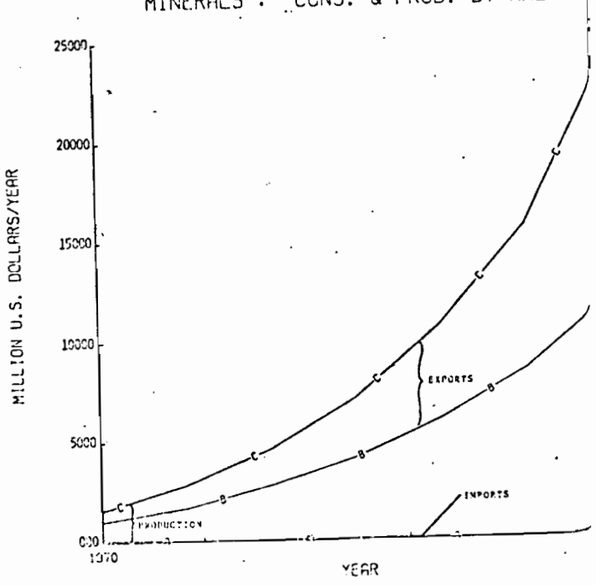


FIGURE 12



made to explore a range of policy options dealing with the interrelated problems of pollution control and, for example, energy use and conservation. Conceivably, it will be possible to examine the macro economic impacts of introducing the *polluter pays principle*, or variations of this policy, in conjunction with, for example, the rapid, wide-scale application of solar energy technology,[12] using the *seed sector* mechanism to introduce the latter. However, because the *environment* sector will be used to examine stress imposed, for example, by wastes and contaminants, permanent restructuring, harvesting activity and manufacturing as well as energy production and use, it is not likely that this sector will be enclosed within the model. Although this post-processing approach will not allow us to assess directly the consequences of environmental responses to imposed stress it should be possible through judicious design of experiments to work toward effecting this goal without incurring prohibitive computing costs.

By incorporating a behavioural description of population growth within the Australian region it will be possible to extend the range of human activities imposing stress on the environment to consider the effects of population dynamics. Development of a means to model migration behaviour will extend this capability to assess the impact of those aspects of world demographic change affecting the Australian population and, in turn, the Australian environment and its natural resources.[13] An existing methodology, which modifies *normal* rates of migration according to indicators reflecting the *level of living* and the material standard of living and the demand for labour,[14] will be extended by developing a *migration-bias* matrix to estimate the form of the migration of labour between Australia and the other regions.

In addition to the foregoing experiments, an attempt is being made to stimulate government agencies and academics in Australia to explore uses of SARUM and AREAM.

For example, there are several agencies interested in extending the analysis outlined in this paper with special emphasis on the means of furthering the economic inter-relationships between Australia, New Zealand, the ASEAN, China and Japan with an attendant ANZ decrease in trade with the EEC and North America. The *resource diplomatic* repercussions of Australia and New Zealand not producing food to feed as many people as possible, say 80 millions, and the impact on their economies of doing so, pose questions worth addressing in a rigorous and systematic manner.

Execution of a whole range of experiments, will be necessary to the process of verifying the model and gaining its acceptance as a tool in public policy making. The activities of model calibration and validation within this process of verification are described qualitatively in an earlier paper which argues that present exploratory work with the AREA model may be a precusor to an inter-agency Commonwealth project.[15]

8. CONCLUSIONS

In summary, we have illustrated the form of a project to extend an existing model of the global economy to deal with international and related national issues affecting Australia and New Zealand. While the project will emphasise the constraints caused by the depletion of natural resources and the impact of human activity on the Australian environment, its potential to deal with a wide range of other issue areas was demonstrated. We saw that the model being extended can take a wide variety of assumptions about the economic system, or about policies that might be taken up, and indicate what sorts of different futures might arise from these. Indeed, in its current form, the user is free to vary all the model's parameters in any reasonable way.

The process of verifying the model and its extensions through peer group and public assessment is well underway. Currently, the project, conducted within the Australian Department of Science and the Environment in consultation with Australian Government agencies and academics, covers a number of aspects which are being conducted in collaboration with the New Zealand Government's Commission for the Future and the OECD's Interfutures Project. Thus, a goal set for forthcoming exploratory work to assess the utility of establishing an inter-agency project within the Australian Government may be extended to include the New Zealand Government - perhaps, eventually, ASEAN?

FOOTNOTES

1. Systems Analysis Research Unit, *SARUM 76 Global Modelling Project,* United Kingdom Departments of the Environment and Transport, HMSO, London, 1977.

2. 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.

3. A.A. Powell, *The Impact Project: An Overview, Vol 1,* AGPS, Canberra, 1977. pp 24-110. Behavioural modelling of Australian population dynamics is described in this report as the BACHUROO Module. It is further considered in a number of working and conference papers, the latest of which "Demographic Model", is being presented at the 49th ANZAAS Congress.

4. Systems Analysis Research Unit, *SARUM Handbook,* United Kingdom Departments of the Environment and Transport, mimeograph, London, October 1978. This handbook should be referred to for full details on methodology underlying model.

5. SARUM 76, *op.cit.*

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

7. *Ibid.*

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

9. An invitation was extended to the SARU team to address the French Senate and present source experimental results.

10. After an evaluation of nine world models ("Midway Through Interfutures" Chapter II) the Interfutures team are using SARUM as their analytical basis, the results of which are forthcoming in an OECD publication.

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

12. J.M. Mula *et al, Solar Australia: Australia at the Cross roads,* Foundation for Australian Resources, Ambassador Press, Granville, 1977.

13. Submission by the Department of the Environment, Housing and Community Development to the House of Representatives Standing Committee on Environment and Conservation, "Impact of World Population Increase on the Australian and Natural Resources".

14. Details of this migration methodology can be found in J.M. Mula, "Exploring Conflicting Views of Australia's Future Using a Systems Dynamic Model", M. Phil. Thesis, Thames Polytechnic, London 1975.

15. D. MacRae, "World-Australia Modelling: A Basis for Australian Resources and Environment Assessment" Environmental Studies Paper AREA-1. Presented to the Mathematics Section of the 48th ANZAAS Congress, 1977.