AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

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

ASPECTS OF A WORLD MODEL FOR

AUSTRALIAN RESOURCES AND

ENVIRONMENTAL ASSESSMENT

by

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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.*

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

Four clearly defined objectives are stated as a
guideline for the development of this exploratory work
within government. The development of the World-Austrlia
model, which forms the core of the project, is based on a
world model developed by the Systems Analysis Research Unit
of the United Kingdom's Department of the Environment. A
description of the structure and economic basis of this model
is given, the model currently having three strata or regions.
The linking of Australia with the world is conceptually
outlined based on extensions of the *bias matrix* principle
to cover both trade in commodities and migration. Another
approach of modelling these international links is described.
The paper concludes with a discussion of incorporation into
the model of anticipated structural change and some possible
applications of the model to the analysis of problems in the
areas of pollution abatement costs, ecological concerns,
climatic change, land and water, energy and food.

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INTRODUCTION

> To consider that world-national models will ever
have utility in Australia is to court vilification.[1] Yet
several national governments[2] are involved in world modelling
for the purpose of playing a part in wider international
studies[3] as and when they emerge. Nevertheless, this is not
a *sufficient condition* for participation by Australia. That
nations such as Japan probably have a better view of
Australia's resource-use potential in a world context than
Australia has itself should, of course, never have been a
condition. That, at present, nearly every element in both
public and private sectors in Australia discourages the
evolution of managers with the skills to develop and use
such models as an integral part of the policymaking process
must begin to contend as a *sufficient condition*. A rationale
for exploratory work in this field in Australia is provided
elsewhere.[4] Briefly, benefits dealt with included:
capitalizing on international developments; stimulating the
dialogue between policy analysts developing and using various
types of national models; perceiving ways to circumvent
objections to high levels of aggregation used in world
modelling; learning from the discipline imposed in model
validation and accounting for uncertainty in model structures
and parameters.

Extreme views held in *economic* and *environmental* circles ensure the exacting nature of the task required to establish a basis for World-Australia modelling. On the one hand, we have the criticism which dismisses all world models and, in Australia, national models. This is exemplified by Mr Stone of the Australian Treasury when he culminates a rebuttal of world modelling ventures with the statement:

> *The Limits to Growth* and its various sequels amount to a greater or less degree, to compilations of pseudo-science directed at those who are wearied of the world, and seek infantile solutions to the problems which they seem to discern.[5]

In essence, such arguments imply that world models only embody the modellers' prejudices, telling us much about the designer, but nothing about the world. Roberts[6] regards this as a form of *nihilism* because, if it were true, it would exclude any possibility of useful model construction. He supposes that critics of this sort probably do not hold the same opinion about models of the natural sciences, and then questions where they would draw the line with models of social systems - are models of national economies to be rejected (c.f. the Australian Treasury's attitude to the IMPACT project[7]), or perhaps models of company operation?

On the other hand, equally trenchant views are embodied in the perception that as rates of change increase, decision-makers are becoming more aware of a central weakness of the economic paradigm - its future to account for delays. This argument continues by reasoning, for example, that a feedback system using free, instantly available, and 100% efficient technologies to cause the abatement of perceived pollution in an exponentially growing industrial system will not be able to prevent expontially rising pollution - simply because of the delay in recognising the need to deploy abatement technologies. Yet economists who perceive the world through a delay-free paradigm will not expect this result and will be unable to cope with it.

These opposing and extreme views need to be reconciled, alone they are not helpful. Furthermore, in seeking a basis for global modelling between these extremes we need to reconcile rather than perpetuate the rivalaries *within* potentially useful economic and ecological framework. For example, within the economic field there is more rivalry than cooperation between the probabilists and dynamicists of econometric modelling. In drawing on ecological constructs, the modelling basis must avoid siding with the dichotomous views developing in environmental circles that the environment is *either* a transmitter of pollutants back to man *or* it may be viewed solely in terms of renewable resources, since, in all probability, neither view is adequate to ensure long-term co-existence of man with nature.

The basis adopted for World-Australia modelling discussed here is the same as that used to assist in framing the discussion paper, recently released by the UK Cabinet Office, on world trends in population, resource and pollution and their implications.[8] A description of selected aspects of the comprehensive work by the UK Department of Environment (DOE) in this field serves to outline the form of the exploratory World-Australia modelling work in progress in the Australian Department of Environment, Housing and Community Development (EHCD). In brief, we will consider:

(a)   the objectives of exploratory work on World-Australia modelling

(b)   the descriptive and neo-classical economic nature of the UK government's world model - more accurately descriptive than the *Limits to Growth* models and without the normative characteristics (e.g. the stamp of fatalism) exhibited in the structures of these models

(c)   the approach to linking world-model and Australia-model structures

(d)   the approach to anticipating change in World-Australia structures (e.g. incorporating a set of relationships describing the production of unconventional foodstuffs into the model, which will only be activated when the economic climate becomes favourable) and consequently achieving a capability for *in principle*   testing of possible future behaviour of the model

(e)   a selection of possible applications of a World-Australia model relating to the analysis of *critical environmental issues*.

Other features of this exploratory work, such as its capability to be used in developing a case for an intra-Commonwealth project to develop a World-Australia model and the use of such a model within the process of policymaking in Australia, are considered elsewhere.[9]

OBJECTIVES

The objectives of EHCD's exploratory work in this field are fourfold. First, to assess the utility of world-national models developed by national governments. Second, to develop and explore the uses of an Australian module for the DOE's world model. Third, to determine in consultation with Commonwealth departments, the range of intra-Commonwealth uses of a World-Australia model using the exploratory work as a basis for illustration. Finally to prepare in consultation with Commonwealth departments, a report specifying an intra-Commonwealth study with the following general objectives:

.   to develop an analytical framework within the political process which will guide long-term policy and planning decisions dealing with the impact of world development, demographic, trade and associated change on Australia's environment and natural resources.

.   to indicate critical times at which decisions will be required, the nature of these decisions and ways of providing suitable advice for making them.

.   to increase awareness in the community of the need to consider seriously the influences of world change on Australia's environment and natural resources.

These objectives are programmatic and do not deal with the primary problems that modelling work of this nature will address. The problems are mainly ones of technical feasibility (e.g. reducing deleterious effects of toxic emissions and persistent insecticides, accounting for resource depletion, compensating for weather variation on food production) and will be considered later in the context of applications of the model. The objective is *not* to discover those courses of action which will avert doom.

OVERVIEW OF MODEL STRUCTURE

The World-Australia model being developed by EHCD is based on the world model developed by the Systems Analysis Research Unit (SARU) of the UK DOE, referred to as SARUM. In SARUM the world is divided into a number of economic strata. Currently model testing uses three strata based on income per capita in 1968 $US as follows: stratum 1 > $3500 comprising the USA; stratum 2 $650-3500 most of Europe, Canada, Japan, Australasia; stratum 3 < $650 essentially the third world - India, China, Indonesia, most of South America and Africa. Total investment for each strata is

estimated from a set of utility curves. This sum is then allocated between sectors by extrapolating past trends for each sector to estimate its future profitability as based on a continuation of past patterns of investment. Trade between strata and sub-sets of sectors is modelled using a basic price mechanism but with a sophisticated trade bias matrix which analyses existing trade patterns and notionally reflects distance, politics, trade barriers as well as price elasticities. The principal interaction between sectors within each strata are shown in Figure 1(a). The emphasis on food is because SARU view its supply as a global problem as much more severe in both the short and long-term than the supply of minerals or energy. From Figure 1(b) we see that the structure of SARUM sectors are based on feedback mechanisms corresponding to the verbal descriptions of classical economics. The continuous line loop is negative feedback in nature and tends to restore equilibrium, the dotted loop is positive, and the dashed lines represent minor effects.

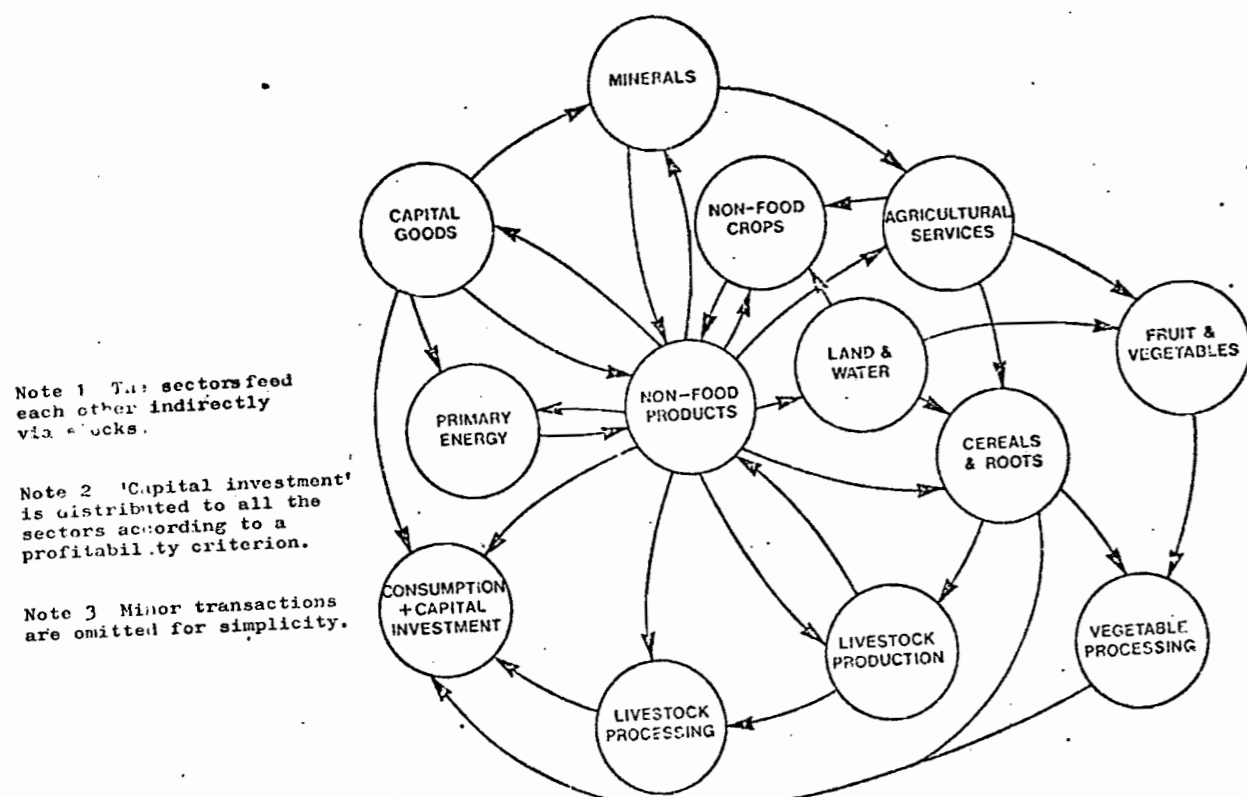The technical report on SARUM describes a sector as having the following attributes[10]:

. A sector is that part of an economy responsible for the production of a specified category of goods or services. Where the category is wide, the sector approximates to a group of industries. For example, an energy sector comprises coal, gas, oil, nuclear and hydroelectricity producers. Where the category is narrow it may contain only a group of like enterprises like the state electricity authorities.

. A sector is characterised by the values of certain variables at a given point in time. Thus, there is a quantity of capital in the form of buildings, machinery and equipment of all kinds. There is a volume of output being produced. Raw materials and intermediate products in defined quantities are being used and labour is employed. The capital equipment is wearing out and being replaced, additional to further equipment being acquired if the sector is expanding. Given the prices of raw

materials, the wage rate, the selling price of the output and the cost of depreciation, the cash flow calculation for a single time interval (e.g. a month or a year) can be performed and a quantity corresponding to profit be deducted.
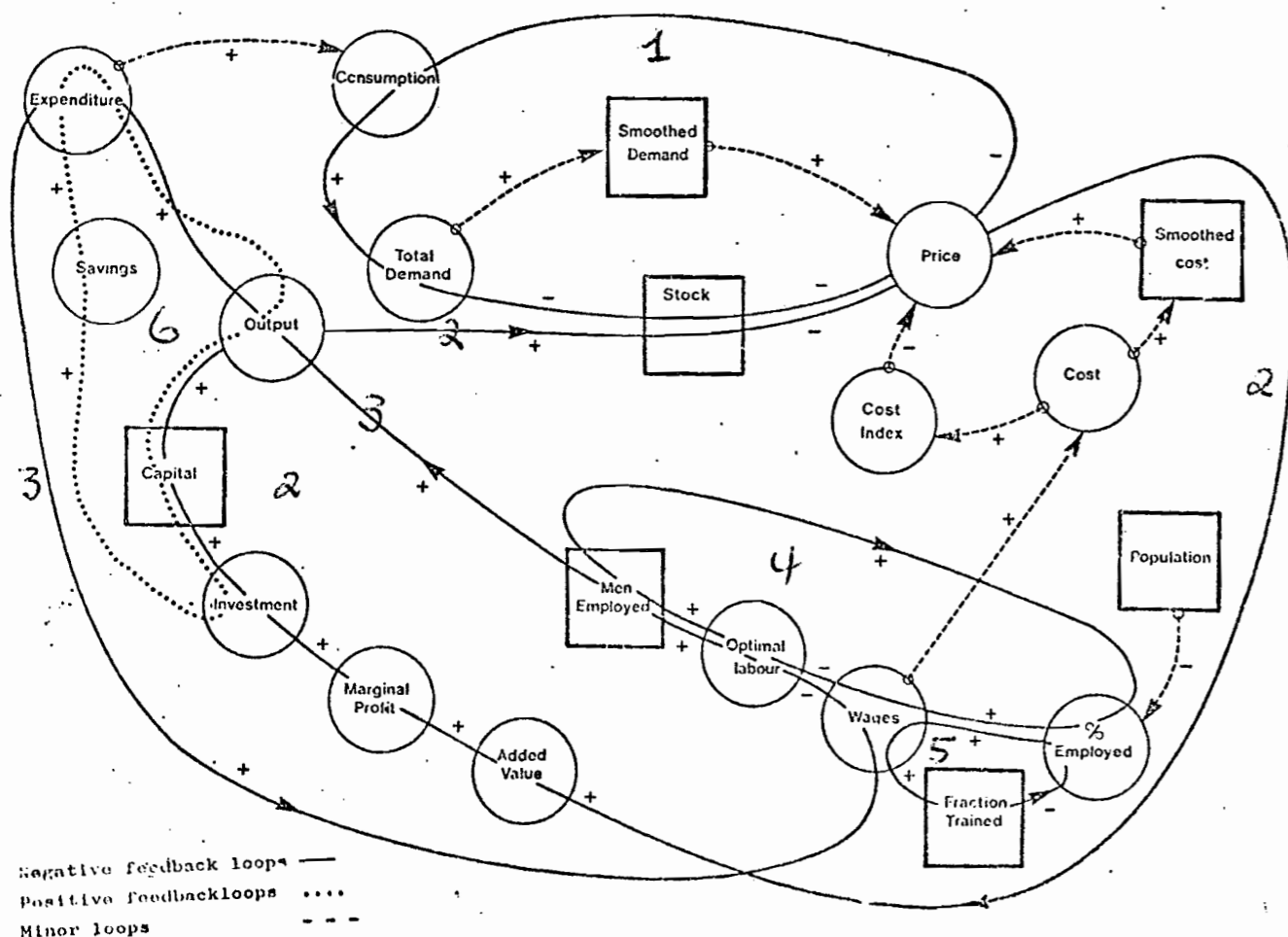
. A sector may be concerned with primary raw material production or it may be buying its input goods from other sectors. The output may be sold to other sectors, or it may be in a finished state and be sold to consumers. For reasons of convenience, industries may be considered as vertically integrated and intermediate products ignored.

Since the model is dynamic, in that it attempts to represent changes through time in response to the driving forces of demand and investment, it goes beyond the content of the input/output matrix framework to describe the inter-connections between sectors. The SARUM report describes the mechanism required as having buffers between the sectors consisting of stocks of commodities.[11] It proceeds by viewing sectors buying their inputs from individual stocks and selling its output to a stock. Temporary imbalances can exist between the rate of production of a commodity and its rate of consumption, the difference appearing as an increase or decrease in the size of the stock. Additional to this buffering function, the stocks also provide a convenient means of driving prices. It is commonly observed that excess production tends to result in price drop and conversely an excess of demand such that there is a production shortfall tends to result in price rise. The modelling of this market feedback is handled by making prices inversely proportional to stock *coverage* values. A coverage value is the time for which the stock would last at current rate of consumption. It is apparent that a variety of functions could be used for price adjustment, but for the purposes of this model there is no advantage in using elaborate functions for relating price changes to production/ consumption imbalances. In this way it can be seen that the price of a commodity will result from the joint effect of all buyers, and that a competitive market is assumed, in that

Figure 1 Basic Structure of SARUM

Note 1 The sectors feed each other indirectly via stocks.

Note 2 'Capital investment' is distributed to all the sectors according to a profitability criterion.

Note 3 Minor transactions are omitted for simplicity.

(a) Interrelationship Among Sectors in each Stratum

Negative feedback loops ——
Positive feedback loops ····
Minor loops - - -

(b) Dominant Feedback Loops

the producer is selling at the price the market will bear. The philosophy of this approach lies in modelling the idealised situation initially, because this is simple to formalise and to understand; reserving the introduction of real world imperfections until these are shown to be important and necessary additions, through contrasts with observed time series and cross sectional data.

Unlike the MIT models, SARUM incorporates production, investment and consumption sectors which are structured on the broad consensus of economic thought. However, in spite of advances in economic dynamics many of the useful theorems about economic behaviour relate to conditions that apply at equilibrium or at an optimum, and say little about how or when a system might satisfy these conditions if it is initially in another state. SARU consider that one of their most exacting tasks has been to develop error correcting algorithms that can guide the model to equilibrium over a time path consistent with actual economic behaviour.[12]

The SARU model is based on relationships between consumption, saving, investment, production, supply and demand, money, international trade and welfare implicit in the synthesis of neo-classical economics, such that other things being equal:

. consumers will choose those goods and services that will maximise their utility given the prices of the goods and services

. entrepreneurs will select that production technique that will maximise their profit given the factor price

. producers cannot affect the price of the goods they sell by adjusting output

. producers cannot affect the price of the goods they buy by adjusting demand

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- labour and investment will flow to those industries where the wages and profits are highest

- prices are an inverse function of stocks

- a set of prices exist that will clear all markets apart from desired stocks

- consumers will buy more (less) of a good as its price falls (rises) and more (less) of a good if their income rises (falls); unless the good is 'inferior'

- entrepreneurs can enter or leave any industry depending on whether they make a profit or loss.

SARU defend the utility of this synthesis in providing a first approximation for modelling purposes, and note that it provides the only quantifiable economic framework that exists because its critics have offered nothing in its place. Their defence relates to clarifying the relationship between consumers and producers, presenting empirical relationships that suggest that free markets are in operation, and finally demonstrating that the behaviour of a model incorporating neo-classical relationships can give an adequate simulation of actual economic phenomena. In this way SARU argues conversely for the validity of the relationships.

In using this as a first approximation independent of the phenomena which distort the behaviour of the system (eg central planning, cartels, barriers to trade, manipulation of demand, monopoly, monopsony, oligopoly etc) the SARU offer the analogy of Newton's system of mechanics:

> One of its axioms states that a body will remain at rest or continue to move in a straight line at the same velocity unless a force acts upon it. We see this law broken every moment of our lives because under terrestrial conditions, friction always brings a body to rest, unless a force is applied to counteract it. This does not prevent the axiom

from being one of the most powerful abstractions ever made. By analogy we suggest that the neo-classical model, suitably modified to simulate the 'friction' in the system, can be used to build a realistic model of the world.[13]

Returning now to Figure 1(b) we see that the variables of a sector (the industry sector selected as typifying sector structures) can interact with one another directly or indirectly to form a system, whose state can be defined by the values of its state variables (the squares). This represents a system in steady state since at least one of the state variables remains constant on average. The system is so organized that departures from this state give rise to effects that tend to bring the system back to the original state. In observing that such disturbance resisting arrangements operate on the principle of homeostasis (which is also characteristic of living organisms), SARU note that systems which do not operate on this principle cannot endure and are therefore not observable. Thus, since "...economic systems endure (temporarily at any rate) they must depend on homeostatis (to a greater or less extent)".[14] As already observed, the variables in Fibure 1(b) are connected to feedback loops arranged so as to maintain constant *stock* (expressed as months of coverage time). To quote again from the SARUM report these loops perform in the following way:

Loop 1. An increase in 'stock' will lower 'price' which will increase 'consumption' and 'total demand' thereby tending to bring 'stock' back to its original value.

Loop 2. An increase in 'stock' will lower 'price' which will decrease 'added value', 'marginal Profit', 'investment' and 'capital'. Because 'capital' is smaller the sector will have less 'output' tending to bring 'stock' back to its original value.

Loop 3. Increases in "output" imply larger payments to the factors of production and therefore to greater 'expenditure' and 'wages'.

However, higher 'wages' will induce employers to substitute capital for labour and 'optimal labour' will fall, to be followed by 'men employed' after an appropriate delay. 'Output' will therefore tend to return to its original value.

Loop 4. Because 'men employed' has fallen 'percentage employed' must fall and this is associated with a decline in 'wages'. As before this leads to a compensating increase in 'optimal labour' and 'men employed'.

Loop 5. A decline in 'wages' leads to a migration of workers out of the industry and therefore a decline in 'fraction trained'. 'Percentage employed' will therefore rise taking 'wages' with it in the direction of the original value.

All the loops described above display *negative feedback* (that is there are an odd number of negative relationships within the loop) and therefore tend to restore the system to its original state.

Loop 6. Is a positive feedback loop which drives the model on an exponential growth path. As 'output' rises 'expenditure' increases. A certain fraction of 'expenditure' (depending on per capita income) is 'saved' and becomes available for 'investment'. The stock of 'capital' is thereby increased and therefore "output" increases also. Provided that there are no depletion effects the model tends to grow at a constant rate dictated by given parameters. However if one or more inputs are becoming scarce 'marginal profit' falls and thus tends to choke off 'investment'.

The structure of the model reflects the assumption that economic systems are demand driven. Our knowledge of the quantities of goods required at each income level is expressed in the form of expenditure curves based on empirical data. As per capita income varies, the way in which expenditure is distributed changes. The relative sizes of the sectors then change in an attempt to duplicate the demand pattern. The speed at which they make this adaption is dictated by the time constants of the model.

Work to-date in EHCD has concentrated on developing an Australia-module for SARUM, similar to that of a single stratum consisting of the sectors shown in Figure 1(a). Eventually, this module may have other sectors uniquely Australian. Certainly, relationships which are beyond the feasibility of a world modelling exercise to develop will be incorporated. For example, causal descriptions of fertility, which link population changes with economic variables, may be incorporated into the Australia - module. This module is being developed to provide a capability for Australian Resources and Environmental Assessment (and referred to as AREA) in a global context; in general terms, to assess the impact of world change on the Australian environment and its natural resources. A significant challenge will be to develop the trade and migration relationships which link SARUM with AREA. Two approaches are under consideration at this stage.

LINKING AUSTRALIA WITH THE WORLD

In representing trade between strata SARU consider that a world model must reflect the following features of the economic system:

.   A country may draw its supplies from more than one source
        even though significant price differentials exist between
        them.

.   A country may import and export the same 'product' if
        the 'product' consists of a heterogenous collection of
        commodities formed by aggregation.

.   World trade patterns react sluggishly to changes in
        relative prices because of habitual business relationships
        and the existence of massive physical infrastructure
        (railways, docks, pipelines, etc) that is ill adapted to
        change.

- Some countries regard trade regulations and tariffs as an extension of strategic and diplomatic policy, and use trade to further their interests abroad and protect special interests at home.

- World trade calls for shipping goods over greater distance than domestic trade and the cost of transport may be a decisive element in total cost at market.

Factors affecting trade such as distance, politics and tariff barriers can be summarized by a trade bias matrix as displayed in Table 1. These values summarise in a compact fashion the world trading relationships and highlight the influence of political blocks on trade. The values of the biases are derived from data on the production level in each region, and a trade matrix of the imports and exports between the regions, on the assumption that prices are constant across the regions. The bias numbers are used to modify the actual prices so that decisions to purchase are made on the basis of a perceived price. However the actual transactions are made at the real price.

TABLE 1 TRADE BIASES (based on 1968 data)

Bias of	Bias against										
	1	2	3	4	5	6	7	8	9	10	11
1. USA	1.00	1.61	2.27	3.24	7.02	3.01	2.76	2.32	2.62	15.52	2.62
2. Canada	2.99	1.00	3.82	4.19	8.44	4.15	4.87	4.14	4.50	8.17	4.18
3. Latin America	3.51	3.45	1.00	3.42	4.60	5.64	5.13	3.70	5.50	6.17	5.14
4. W. Europe	2.85	2.25	2.28	1.00	3.03	1.79	1.56	2.88	2.09	4.22	2.10
5. USSR + Europe	7.73	4.64	3.61	3.28	1.00	-	2.97	4.77	3.67	4.00	4.25
6. S. Africa	6.27	5.35	8.42	7.67	-	1.00	4.13	5.06	4.96	-	5.10
7. Less developed Africa	5.31	5.73	5.85	3.09	4.87	2.30	1.00	3.39	3.68	5.27	5.15
8. Japan	3.95	3.13	3.60	4.63	5.45	2.51	3.21	1.00	2.48	4.62	2.39
9. Less developed Asia	3.49	3.72	4.90	3.00	4.38	4.31	3.18	2.27	1.00	3.41	2.79
10. Centrally Planned Asia	-	4.43	5.69	5.67	4.63	-	4.96	4.32	5.69	1.00	4.14
11. Australia & New Zealand	5.14	3.98	8.71	4.11	11.63	4.75	6.02	3.86	3.90	7.56	1.00

A trade barrier of unity implies completely free trade with no tariffs present, and a value of infinity implies that all economies attempt complete self-sufficiency. If there are no trading countries or blocks and a given good has price ρ_j purchased from the jth country, then a proportion ϕij of demand is satisfied by supply from the jth country. A bias bij is postulated so that

$$\phi_{ij} = f(b_{ij} \rho i)/_k \overset{n}{\underset{=1}{\Sigma}} f(b_{ik} \rho_k) , \quad (b_{ii}=1)$$

where f is some monotonically decreasing function such as $f(x)=x^{-\gamma}$. As a consequence of trading activities some strata show a surplus on their balance of trade and others a corresponding deficit. This cannot continue indefinitely because the international financial organisations (e.g. World Bank) and other creditors insist that debts be repaid. Failure to comply may lead to withdrawal of credit facilities in future.

In the course of inter-stratum trading and aid programmes there will in general be a net flow of money into or out of a stratum. The exchange rate, which relates the buying power of the stratum's currency to that of the 1968 US dollar, is increased or decreased by a factor comprising a parameter times the ratio of the accumulated debt to the gross stratum product. Trade and aid result in a flow of money into or out of the stratum, which is the current deficit. Debts of repayment is a fixed fraction of the accumulated debt. Cummulative debts are not reduced to zero, but remain at a small percentage of total expenditure representing the difference between the *debt erosion* and the accumulation from debts. For high rate of erosion the residual debt is small but overall behaviour is insensitive to the size of this parameter. Net aid is the summation of the aid flow into the stratum, corrected for exchange rate differences and the aid flowing out of the stratum. The trade bias modifies the expenditure trade fraction and the perceived price – the perceived price being the retail price (wholesale price

plus retailing services) modified by the trade bias and exchange rate. The net outflow or inflow of money for each stratum is the combination of the balance in current trade or deficit arising from imports of intermediate and consumer goods, with the net effect of aid transactions.

The movement of people (i.e. migration) is modelled in a limited sense. Reference is made, in calculating the desired labour force to the *Fraction Trained*. Fraction trained is a mechanism for determining the growth or decline of the potential labour force of a sector. The term *training* is deemed to include geographical relocation as well as training in the sense of acquisition of specific skills. Movement of labour into a sector's trained labour force is driven by wage rates. If the wage rate in a sector is greater than the weighted average over the sectors in a stratum, labour will tend to migrate to the sector. However, this movement is only between sectors. No attempt has as yet been made to model movement between strata.

Mula[15] has proposed an alternative means of linking world and national models. He uses the structure outlined in Figure 2 to link a modified version of the MIT's world model to an Australia model based on an extension of the former. Figure 2 in this case depicts the form of a possible set of links between SARUM and the Australia module (AREA). The assumptions underlying Mula's trade structure, represented by minerals, energy, food and industrial goods are as follows:

- exports and imports are always balanced in total at some point in time

- due to response delays in demand and supply of commodities, this trade balance is disturbed

- total trade is measured in 1970 constant dollars but is converted into commodity units by a constant 1970 export price
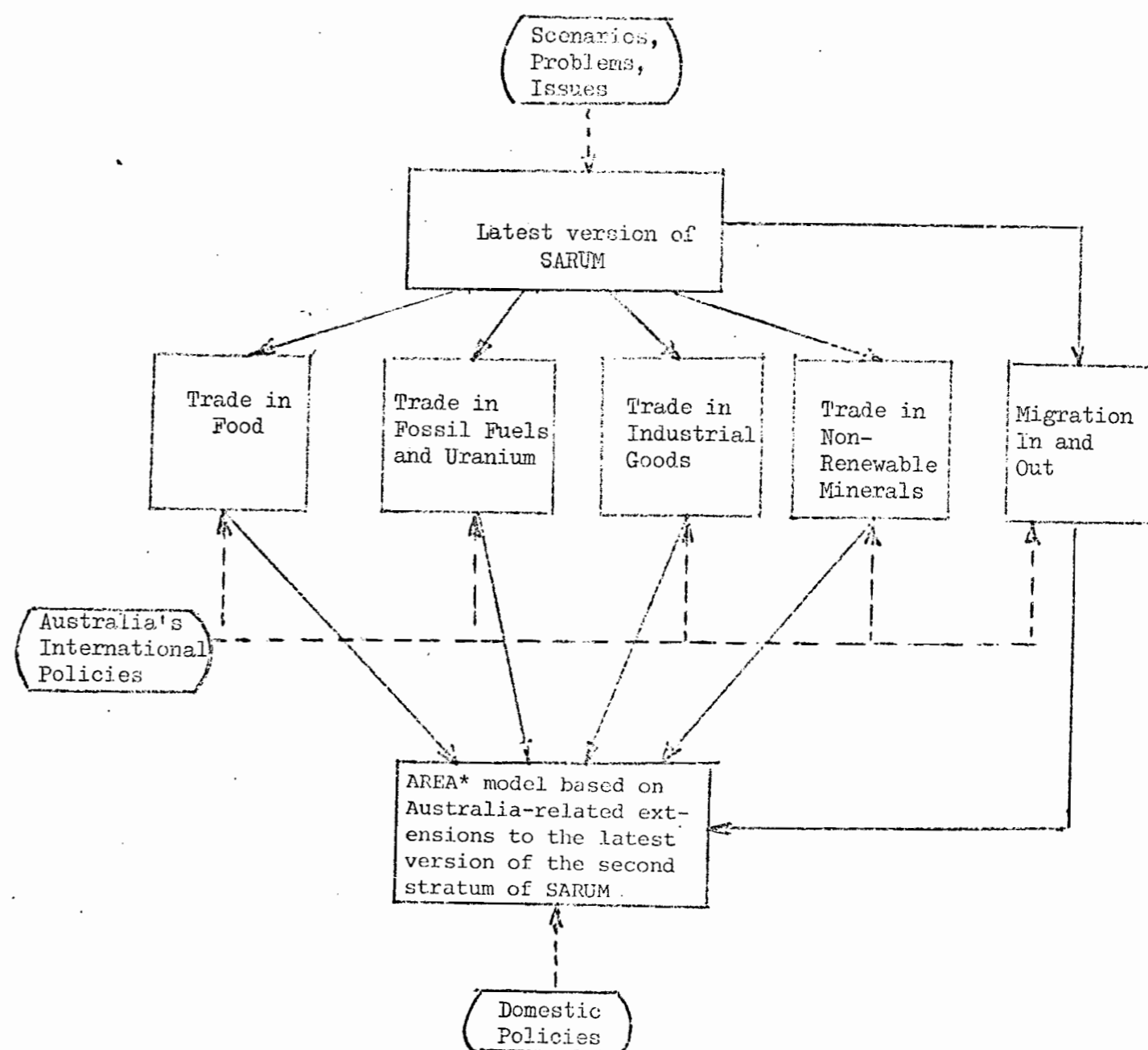
* Australian Resources and Environmental Assessment

FIGURE 2. BASIC STRUCTURE OF TRADE-MIGRATION LINKS

- exports respond to the ability of the world to trade; these responses are indicated by important world variables, namely

  - availability of minerals by the per capita non-renewable mineral resource usage

  - availability of energy by the per capita non-renewable energy resource usage

  - availability of food by the food ratio

  - availability of industrial products by the industrial output per capita

- exports are determined by a fraction of home production or consumption being modified by the availability of the commodity for export, the world's ability to trade, and the desired policy for export of the commodity

- imports are determined by trading off one commodity for another by the use of a substitution multiplier and modified by a self-sufficiency multiplier and world availability of the commodity to be imported

- import response is delayed to account for demand and supply phenomena

The main casual loop in this trade cycle is negative and basically describes the situation which says if exports are increasing then imports can be reduced.

Migration is specifically modelled here unlike the SARU model which only models inter-sector migration of labour. Migration is defined as the net flow of all people entering Australia. It is the difference between total arrivals and total departures. Thus no differentiation has been made between permanent and short-term arrivals and departures. Some of the assumptions that are basic to its structure are as follows:

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- Net migration enters the population and is assimilated into the population on the same structural basis which exists on its entry

- Migration in and out can cancel each other out, in other words a net migration of zero

- The balance in the flow will be disturbed by a more favourable or less favourable state in either the world or Australia

- This favourable or unfavourable state is indicated by three important factors:

  - material standard of living which is determined by the industrial output per capita

  - life's quality which is determined by life expectancy

  - demands for labour which is determined by the unemployed fraction or the demand for labour.

The state of the world and the state of Australia as described by three indicators determine rates at which people flow in and out. In choosing these indicators, attention was paid to the overwhelming demands for labour to fill vacancies. This demand is indicated by a migration from demand for labour function.

ANTICIPATING STRUCTURAL CHANGE

Technical progress consists not only of steady improvements in productivity but also of the emergence of totally new sectors whose key features cannot be foreseen prior to their invention or development. Environmental and resource shortage factors put a limit on the production of certain sectors of the economy. They may act in one of two

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ways, either as an absolute upper limit to the production
rate (flow limited sectors), or as increasing cost with
time-integrated production (stock limited). Clearly, if a
flow or stock limited sector is vital to the economy,
then it must lead either to an end to economic growth or
a progressive collapse respectively. This can only be
avoided if some alternative resource, or strategy, can
be introduced to replace the depleting sector. Thus the
emergence of new sectors is modelled by postulating *seed*
sectors - sectors in embryo form which can grow when the
economic climate becomes right.

Seed sectors may operate to produce output
identical to a depleting sector for which it is a substitute.
Or its products may be different, but regarded as substitutable
in most instances (e.g. aluminium for copper, solar power
for coal, single-cell protein for meat). Or its product may
be of a totally different nature, but it may represent the only
way round the problem of depletion (e.g. if no new energy
sources can be found, investment could be directed to energy
saving schemes).

In modelling, the real-world, past and future, is
reduced to factual descriptions that are readily managed.
Nevertheless, it is a complex task to determine whether
these descriptions represent positive analogies in the
real-world situation in all aspects previously tested, and
provide the capability of exhibiting possible future
behaviour which can be tested in principle. SARU have found
that with respect to the latter that realistic inclusion
of anticipation of structural change in the model fundamentally
affects the predicted harmful effects of resource depletion
and in some cases removes them altogether. They claim that
this will allow the model to produce more realistic
predictions and to be used by policy makers in their
evaluation of various investment strategies.[16]

APPLICATIONS

Exploratory analyses which SARU are currently
undertaking include:

- assessing the effect of resource constraints arising
  from both and stock flow limits in the presence of
  population growth and technical progress

- exploring the results of changes in income distribution

- examining year to year weather variation on food
  production

- simulating shifts in trading relations

- considering the influence of 'seed' sectors
  growing to fruition during a run and the degree
  of anticipation exercised during a substitution

- examining the consequences of various types of transfer
  other than trade between the strata e.g. aid in the form
  of migration of labour and labour and investment as well
  as gifts or loans

- exploring the consequences of cartel action by specific
  groups of producers

- exploring the need for measures to reduce the toxicity
  of emissions from industrial plant and, at a more general
  level, the deleterious effects of a wide spectrum of
  persistent insecticides and the potentially long-term
  damaging results of pouring nitrogen oxides and carbon
  dioxide into the atmosphere.

Of most interest to EHCD are problems relating to pollution
abatement costs, ecological concerns, climatic changes,
land and water quality and energy conservation as well as
those relating to what SARU see as the major problem - food.

The following discussion of problems is drawn mainly from the environment section of the 1974 UN Social Situation.[17]

Pollution abatement costs

A World-Australia modelling project involving EHCD would seek to explore the need for measures to reduce the toxicity of emissions from industrial plant and, at a more general level, the deleterious effects of a wide spectrum of persistent insecticides and the potentially long-term damaging results of pouring nitrogen oxides and carbon dioxide into the atmosphere. Because the proportion of output necessary for pollution abatement may conceivably exceed that obtained from growth, this aspect of the system justifies representation in a World-Australia model. Social factors which make this very difficult include: (a) the value which societies place on avoidance of noxious substances - and environmental damage depends on the surplus when basic needs have been satisfied; and (b) the reactions of societies depend on the strength of the signals which indicate danger - from long-term persistent pollution this may be weak, and the action necessary to avert it therefore comes too late to avoid the consequences of its build-up.

Ecological concerns

The loss of genetic diversity through the extinction of populations and species, the modification of habitats and the decay of variability in gene pools are areas of ecological concern. This might extend to the human genetic pool which could be altered not only by spontaneous mutation, chemical mutagens and ionizing radiation but also by patterns of population growth or control; the genetic implications of demographic policies demand careful study but have received almost none. Such discoveries give cause for concern over man's abuse of both marine and terrestrial life-support systems whose stability and productivity are essential to

our own. Very little is known about the dynamics and widespread ecological destabilization, or, for example, about the ability of marine and coastal systems to withstand various insults.

Climatic change

It is known that several major human influences on global circulation (heat, carbon dioxide and particulates) may tend to act in the same direction in certain respects; that man may already be affecting global climate, particularly in the monsoon belt; and the critical determinants of global climate are more sensititve to perturbations than had been thought. There is already reason to view with concern major alterations of water flows, or evaporation patterns and of surface optical properties through, for example, deforestation. Even the controversy over the effects of civil aviation on stratospheric chemistry is not yet resolved. Because of the precariousness of the world food supply global models are being used to focus on the consequences of short-term regional instabilities in climate - periods of persistent aberrations from the mean on a time-scale of seasons or years. The phenomena may be repeated droughts - or, in some areas, grossly excessive rainfall. The environmental manager, who must plan on the basis of the extreme rather than the mean, would like to know how often disastrous years such as 1972 will recur; hence, he must know whether bad years tend to coincide in different regions by mere coincidence or by causality. This is a fairly new subject of intensive empirical and theoretical study fully as difficult as it is important.[18]

Land and water

Two of the major questions of national water quantity and quality might be addressed through global-national models: irrigation of arid regions and conservation

of clean water. Massive irrigation, for example, is thought by some experts to be irreversibly harmful to fertility owing to salination. Further, many experts now believe that irrigation will in most areas contribute too little and too late. Only about 2.5 million square kilometres (2 per cent of all ice-free land) is now irrigated, at great cost and with many unwelcome side-effects. Properly irrigating the main arid and semi-arid regions of the world would require the use of the total continental run-off, a physical impossibility, and water projects so large as to risk substantial changes in regional global climate. On the question of water quality, all areas desperately need cheap, simple and foolproof technologies for conserving clean water, removing pathogens and recycling dissolved nutrients. Water quality in many poor countries falls far short of the safety standards of the World Health Organisation, posing immediate epidemiological hazards and greatly complicating the formidable problems of dense human settlements. In the longer run, the absence of recovery technologies may soon impose an outer limit on intensive agriculture because of the escape into surface and ground-waters of nitrogen, phosphorus, pesticides and other agricultural additives. The long term effects of these substances on soil microbiota are conjectural. Industrial nitrogen fixation, already of the same magnitude as the natural microbiological process, is projected to increase a hundredfold in this century and is already viewed as a potentially severe hazard to water quality through both eutrophication and human toxicity. Phosphorus use is increasing about 2.7 times as fast as population; its fate in the biosphere and its long-term availability as a mineral resource are largely unknown.

Energy

The implications for a World-Australia model would appear to be that economic pressures will force a rational policy for industrial and domestic waste disposal in the face of rising fuel and raw material costs. In the energy

sector we can expect that in the long run all the fossil fuel sources will be exhausted and that continued reliance on nuclear power will lead, increasingly, to severe problems of waste disposal and thermal pollution. Ultimately our society can only coexist with the ecosystem if our agricultural and manufacturing activities are in equilibrium with our environment. This implies that the composition of human artifacts should reflect the composition of the environment. Also that energy needs should be satisfied by diverting a fraction of the solar energy to satisfy human requirements. This places a flow limited upper bound to the rate at which energy can be used and consequently limits to population, food production and standards of living.

Food

Recent reports on the race between agriculture and population are ominous, especially for countries whose food prospects have long been unpleasant because of momentum inherent in a skewed age structure. For this reason the UK DOE's world model has initially been structured to focus on the global food problem.

Food supplies are being threatened not only by population growth but by the demand for animal protein inspired by rising affluence. This demand is now a major claimant on scarce supplies of both grain and feed-stock proteins. The latter are on the whole exported from poor to rich countries, where they are converted into animal protein providing one-tenth to one-fifth as much food value at a higher price. Grains - more than half the world's direct food supply are consumed directly at a rate of about one pound per capita per day in most poor countries. Some rich countries consume less grain directly, but they consume grain at over twice that rate indirectly in the form of meat and beverages.

Not real expansion but costly, unexpectedly slow, and ecologically risky intensification has accounted for most increases in world crop yields since 1950 - for four-fifths since 1970. Readily irrigable land and the water needed to irrigate it have accordingly become extremely scarce. Thus, further intensification is subject to diminishing returns. The long-term fertility of established farmland is jeopardized not only by the poorly understood chemical, ecological and mechanical stresses of intensification but also by indirect population pressures. These include overgrazing (which is responsible in part for the annual advance of the southern Sahara of 2 to 10 kilometres), deforestation of uplands (which may increase lowland flooding), increased farming of fragile uplands (which may silt lowland irrigation systems), urbanization of prime farmland, and the direct and indirect side-effects of mining.

Such forces are rapidly changing the world food market, like the world energy market from a buyer's to a seller's province. A global picture of food scarcity, especially of protein, is now emerging with disquieting implications both for hungry people and for world political stability. This new situation will be reflected by: (a) competition for exportable grain among countries of widely varying wealth; (b) a growing tendency for main world suppliers of agricultural commodities to withhold supplies from hungry customers for domestic political reasons; (c) greatly increased volatility of prices in all countries because supply deficits in the past three years have virtually eliminated the two main buffers the post 1960 land bank of the United States of America and world grain stocks; responses of prices at relatively small pertur-bations will therefore become more common; (d) the increasing monopoly of midwestern North America, which controls about two-thirds of the world's exportable cereals and over 90 per cent of the world's exportable soybeans; (e) the resulting vulnerability of world food supplies to weather in that region - a region subject to a regular 20-year drought cycle due to recur about now; (f) as scarcities increase,

a tendency to view food as a strategic commodity to be controlled in accordance with political goals.

These problems are not merely imminent but already here. Safety margins are being continuously eroded. Another international crop failure like that of 1972 or the recurrence of a *dust bowl* like that of 1932 in the United States could now trigger major regional disasters.

CONCLUSIONS

To put SARUM model results achieved in late 1976 and the foregoing *critical environmental problems* identified in the UN Social Situation report in perspective, we conclude by quoting the conclusions of the UK Cabinet Office discussion paper (which drew on the broad results emerging from the use of SARUM) on world trends in population, resources, pollution and their implications.[19]

1. Worldwide, by far the most important factor in the future will be the growth in population, occurring overwhelmingly in the developing countries and the consequent problem of providing adequate food. In the absence of famine, war or other disaster a steep rise in the World's population for the next two generations is inevitable and by the end of the next century the figure may well be in excess of 12 billion. Unless current fertility rates can be cut in the immediate future the population of the developing countries alone could in theory rise to 6 billion by 2000 and 15 billion by 2025, but widespread famine with all the political unrest which this would create would almost certainly prevent this in practice. A delay of one generation in achieving a stable population level could increase the world's population by 70 per cent.

2. Although it should be theoretically possible to feed the world's growing population until the turn of the century,

the enormous political, social and economic problems involved make it unlikely that this will be achieved. Market forces will probably work against the equitable distribution of food because of income disparities. Moreover resource costs, particularly that of energy to produce fertilisers and for transport, will be so large that a major proportion of the world population is unlikely to have either the resources to produce sufficient food or the income to buy it at prices which would cover the cost of production.

3. Unless there are resource transfers on a scale many times greater than at present, the effective check to world population will be the Malthusian trilogy of war, famine and disease. This is an urgent problem, but at present aid and other capital flows are falling as a percentage of GNP of the developed world as a whole and it is by no means clear that those donor countries who can afford to do so would be prepared to provide aid on the terms and scale needed. As lower birth rates seem to result from increasing standards of living, failure to raise real incomes will militate against the success of population control measures and further exacerbate the long term situations.

FOOTNOTES

1. See, for example J.O. Stone's rebuttal of world modelling ventures in the paper "Economic Growth - Threat or Promise?" Address to the Public Service Board Second Division Seminar, March 1974. It is also of interest that while Australia commits considerable funds to the maintenance of the OECD that it has not sought to participate in the OECD's major global modelling project INTERFUTURES, which has been in progress for one year of a three or four year programme.

2. For example, the UK, USA, Argentina and Japan. These developments are briefly considered in D. MacRae, "World-Australia Modelling: A Basis for Australian Resources and Environmental Assessment" 48th ANZAAS Congress, Melbourne, September 1977, and in "SARUM 76: Research Report", Department of the Environment, London, UK, 1977.

3. The OECD project INTERFUTURES and a joint project being conducted by the United Nations Environment Programme and the International Institute of Applied Systems Analysis.

4. D. MacRae, "World-Australia Modelling - A Basis for Australian Resources and Environmental Assessment", 48th ANZAAS Congress September 1977.

5. J.O. Stone, "Economic Growth - Threat or Promise?", *op.cit.*, pp. 24-25.

6. P.C. Roberts, "SARUM 76 - A Global Modelling Project", *Futures*, February 1977, p. 4.

7. The IMPACT (Impact of Demographic Change on Australian Industry Structure) project is an intra-Commonwealth agency venture, involving the Industries Assistance Commission, Australian Bureau of Statistics, Department of Industry and Commerce, Department of Employment and Industrial Relations and Department of Environment, Housing and Community Development - but not the Treasury, a fact which has received considerable comment in the national press.

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

9. D. MacRae, *op.cit.*

10. Systems Analysis Research Unit, "SARUM 76: Research Report", Department of the Environment, London, UK, 1977, p. 2/1.

11. "SARUM 76: Research Report", *op.cit.*, p. 2/2.

12. "SARUM 76: Research Report", *op.cit.*, p. 2/6.

13. "SARUM 76: Research Report", *op.cit.*, p. 2/12.

14. "SARUM 76: Research Report", *op.cit.*, p. 2/24.

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

16. "SARUM 76: Research Report", *op.cit.*, p. 2/54.

17. "Environment", *UN Social Situation*, 1974.

18. R.A. Bryson and T.J. Murray, *Climates of Hunger: Mankind and the world's changing weather*, ANU Press, 1978.

19. *Future World Trends*, *op.cit.*, p. 24.