



## **Chapter 8**

### **Overview of the report by the External Reference Group**

**From  
Future Dilemmas: Options to 2050 for  
Australia's population, technology,  
resources and environment**



Report to the Department of  
Immigration and Multicultural  
and Indigenous Affairs

By CSIRO Sustainable  
Ecosystems

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# Chapter 8

## Overview of the report by the External Reference Group

### *ABSTRACT*

In assessing the merit of the CSIRO study, the External Reference Group notes the tension between the depth and understanding of each of the disciplines represented in our group and the extent to which these intricacies are portrayed in the modelling approach and the results reported. Inevitably, each portion of the study does not itself represent the state of the art in each of our disciplines. However the study effectively brings together many individual issues in demography, the physical sciences, ecology and economics that normally remain unconnected in many national policy processes. Therein lies the strength, in both the scale and the connectedness of the study. The CSIRO model is different from most national models in that it simulates the physical processes that underpin the functioning of the nation, the so called 'physical economy'. In our critique of the approach and the results, we asked to what degree the disciplines of demography, economics and ecology were appropriately represented in the study. In general we were satisfied that the conclusions of the study are robust and defensible. We found that the results related well to the published literature, including in those areas where the analyses themselves were necessarily limited. From our perspective, there are three important learnings from the study, and the social process that surrounded it. The first is that the complexity and richness of the analytical approach affords both government and business the ability to look across sectors and institutional silos in a long-term context that spans human generations. Secondly it provides an empirical basis to refresh the national debate on sustainable development. Thirdly it suggests that federal government policy should focus mainly on managing national stocks (people, infrastructure, energy and natural resources) rather than national flows. In the main, the shorter-term national flows should be left to the fleet footedness of market forces. Finally the study demonstrates that no one population scenario represents an unalloyed good – a clear and unrestricted path to the future. Instead it shows that each scenario creates its own opportunities and challenges that need resolution at the policy table, and eventually at the household level. A moment's reflection suggests that this is good common sense. We would be alarmed and suspicious, knowing what we do about the way the world works, if there appeared to be some 'Yellow Brick Road' to the future.

### *INTRODUCTION*

What are we to make of something that tries to look at everything when we usually spend our days looking at some particular thing? In an age of ever-increasing specialisation, how are we to cope with generalisation? This is the task and dilemma facing the External Reference Group, specialists all, in commenting on this report. It is a dilemma compounded by the fact that our specialities are all different – that while we each know a lot about our own specialisation, we know much less about our colleagues'. But we have come together, at the request of the Department of Immigration and Multicultural Affairs, to provide an independent frame of reference for the report.

Our group comprised Roger Bradbury (Australian National University, chair, ecology), Ian Burnley (University of New South Wales, human geography), Chris Murphy (Econtech, economics), Chris Ryan (RMIT University, technology) and Mark Wooden (University of Melbourne, economics) and was ably assisted by Neil Mullenger of the Department.

Within each of our specialities – whether it is economics or ecology, demography or technology – our task seems relatively simple: we need only to compare those aspects of the report that bear on our native discipline with what we understand to be 'best practice' or 'leading edge' or whatever is

the current jargon for what the best and most creative people are doing. And if we do that, the answer will be simple and crisp: this report is not ‘leading edge’ in any of our disciplines. However a moment’s thought reminds us why this is a trivial response, one which sidesteps the reason we have come together. On reflection, we should expect that a study of everything, using tools and techniques which are not mainstream within any of our disciplines, cannot produce insights or understanding within a discipline that are better than a study of some discrete phenomenon, using finely honed tools and specialised techniques peculiar to that discipline.

The very things that make for the success of specialisation also create its own Achilles’ heel. We spend so much time mastering the details, that we have trouble with the whole.

To gain the benefits of specialisation, and to survive in the modern world, we have had to forego our heritage from Renaissance Man, that ideal creature, personified by Leonardo da Vinci, who knew everything there was to know. To reclaim that heritage we need to become a Renaissance Team. Thus our Group needs to take a different tack in its approach to the report, one that does not dismiss the claims and arguments of the specialist, but rather one that puts those claims and arguments into the context of the whole. We need to see, say, the ecology or economics in the report from two points of view: one which looks into the discipline concerned and examines it from the perspective of that discipline, and one which looks out from the discipline and examines it from the perspective of the ‘problem of everything’. And we need to have these perspectives simultaneously.

We need to ask, not ‘What does this piece of the report contribute to the discipline?’ but rather ‘What does the discipline contribute to the whole problem, through this piece of the report?’

Thus the fact that the report cannot mix it with the ‘leading edge’ within any particular narrow discipline does not mean that it is not ‘leading edge’ in itself. The report needs to be judged on its own terms as an attempt to look at the whole and not the parts. It needs, to be sure, to offer competent and thoughtful analyses from the perspective of any one discipline, but it also needs to be judged on the extent to which new understandings of the larger problems emerge from the interplay of the various specialisations and disciplines.

In our discussions during the course of the project this tension was obvious, as it is in our comments here. Nevertheless we have striven to provide a framework within which specialised issues may be discussed and argued on their own terms and in terms of their contribution to the whole enterprise.

In addition to the broad analysis and critique for which we take collective responsibility, we have also included some amplifying material in separate boxes. These comments focus on some disciplinary issues a little more deeply, and are attributed to individual members of the External Reference Group.

### ***APPROACH – CONTEXT AND CRITIQUE***

Our objective in this chapter, therefore, is to provide a context for, and a critique of, the CSIRO project, drawing on the range of expertise within the External Reference Group.

The discussion of the **context** will seek to embed the report within the large body of work in both the natural and social sciences on population issues in particular and modelling in general. It will explain where the CSIRO approach fits *vis à vis* other work in these areas. It will acknowledge and describe the report’s multidisciplinary ‘heritage’ while providing an overview of its own contribution to the population and sustainable development debates.

The key contextual issues we will examine are:

- The use of models in science – and how to read them – with particular reference to the report.
- The biological tradition *vs* the economic tradition (that is, natural *vs* social sciences traditions) – the key similarities and differences between modelling and simulation in the social and natural sciences, with particular emphasis on the approaches of economic and ecological modelling – as sources of understanding and confusion.
- The problem of sustainable development as an interaction between biophysical and socio-economic processes – and, thus, how to place the report in the context of sustainable development.

The **critique** will be a more focussed analysis of the general strengths and weaknesses of the issues chapters and the crosscutting analysis.

- Are there ‘issue’ sub-models with counterpart ‘disciplinary’ models? One of the strengths of the design framework approach is that it can produce both single-issue models, such as population, employment, energy and water, as well as holistic models synthesising all the issues. But for each of these issues models, other ‘disciplinary’ models exist. How well do these models relate to each other? What can we say of any differences that we observe?
- How are the soft systems joined to the hard systems, and what can we say about it? The report makes much of its basis in physical reality, but much (beyond the actual three population cases driving the scenarios) depends on how the softer, more subjective aspects of the problem (such as the degree of acceptance of technological change, or of different lifestyles) intrude into the analysis. Does the report handle this well, and are there other ways that could be used?
- How is ‘the physical economy’ distinguished from ‘the (monetary) economy’ — or how does economics get a look in? The report makes it clear that it is not a ‘traditional’ economic analysis, and argues that it should sit side by side with such economic analyses. It argues that its strength is that it provides policy makers and the public with additional avenues of understanding. That said, there is still room for some analysis on how notions from the one approach can be represented in the other, beyond relatively trivial procedures like contingent valuation. Can we use the notion of information (as a notion as fundamental as energy or mass) to give some scope for ideas about markets (which are essentially information processing objects) to penetrate the model?
- Creating the link between people and their environment – or how does demography get a look in? An analysis of how the sustainable development debate often does not include one of the key drivers – human population – and how this report makes a significant attempt to remedy that problem.
- How does the model deal with the essentially spatial notions implicit in the concepts of sustainable development – or how does ecology get a look in? In linking population to the physical environment, the report moves solidly into the debate on sustainable development. One of the key concepts here is that of spatial distribution – it matters not only how much or how fast things happen, but exactly where they happen. From this flows an idea about the

graininess or heterogeneity of processes. The present model makes some attempts at this, particularly in terms of population. We will examine the sufficiency of the report's spatial thinking, and the effects this may have on its conclusions.

- How does the model deal with innovation and change, both technological and social – or how does 'Factor 4' thinking get a look in? The report attempts to project not only physical trends but also intellectual, technology and social trends, with its thinking being informed by the results of the workshops. How well is this aspect of the work done, and what can be said about it in comparison to what else is being done around the world?

## **CONTEXT**

### **The use of models in science**

Modelling is so very close to what doing science mostly is that we often confound them (Bradbury, 1997). More than that, we often make the assumption (either implicitly or explicitly) that, since there is really only one kind of science, that there must be only one kind of modelling. And that leads to all sorts of misunderstandings not only about modelling, but also about the science that flows from it (Bradbury, 1999). In its simplest form, this problem is expressed in the inability or unwillingness to understand another's models. In a more perverse form, it is seen in the inability or unwillingness to accept the contribution to understanding that another's models might make.

Here, we will explore the nature of the model used in the report and its relation to other sorts of modelling, remembering that the model is the tool, the means to an end. It is the scientific understanding that is the end. While the model may colour that understanding, may inhibit or enhance it, it is not the understanding itself.

Modellers choose their models not only for the job in hand – their intended use (Pielou, 1981) – but also for their ease of use – their structure (Hogeweg and Hesper, 1985) – and the type of understanding they seek – their philosophical bias (West, 1985). These three different characteristics of models are more or less independent of one another. The result is that there are potentially a lot of different classes of models, many more than most modellers believe. Indeed, when modellers talk of different models, they usually mean different models within the one class – the class they use. Much of the debate and confusion about modelling – a sort of academic white noise – is caused by this myopia.

Most workaday models in both the natural and social sciences have as their intended use some sort of prediction, but there are at least three other quite distinct uses of models: explanation, hypothesis generation and as standards of comparison. Similarly, most models have an underlying structure that is variable-oriented, which is to say a structure built on the behaviour of variables linked together in mathematical equations. But individual-oriented (sometimes called agent-based) and event-oriented models are each distinctive alternatives. Finally, there are at least five kinds of truth that models may seek: Lockean or empiric; Leibnizian or analytic; Kantian or synthetic; Hegelian or dialectic; and Heisenbergian or pragmatic. Most modellers see themselves as synthesisers, but the other classes are just as justifiable.

The CSIRO model that underlies the report is quite different from most models in use today. Firstly, in its emphasis on scenarios, it is being used to generate hypotheses not to test them. So it immediately distinguishes itself from the raft of models that seek to predict (many of which also claim to explain). Secondly, it is event-oriented, the different components of the model sending messages to other components to which those components then respond. This is quite different from

many ecological, economic or demographic models based on sets of mathematical equations. Lastly it is empiric in its attempt to describe its world as a physical economy – a practical, hard-nosed realistic description of how this world actually works. This is quite distinct from more analytic or synthetic models that embed their work in a framework of theory.

## **How to read the CSIRO model**

Since the CSIRO model does not aim for prediction, its results need to be treated differently from those of more traditional predictive or explanatory models. In such models, the results purport to inform us about the way the world is – by explaining – or about how it will be – by predicting. Thus their results form part of a story whose beginning is a description of how the world is, whose middle is an argument about how the bits of the world interact, and whose ending – the model results – is the dénouement: either why it is so (the explanation) or what it will become (the prediction). Thus such models can be read quite easily as the ending to the story.

Models that develop scenarios are different because they have a different relationship to the rest of the story. And so they need to be read differently. Scenaric models are not an ending to a story about the way the world is. Instead they are beginnings of new stories, but fictions to the facts of the earlier ones. That is, they take, as a beginning, the way the world is, and then, as a middle, they ask ‘What if ...?’ – making a plausible case for the way things might be. Finally they unfold their ending as the working through of the interactions of the model.

It is important to note what we mean here by ‘fictions’: a plausible, scientifically lawful description of the possible. We do not mean ‘fantasies’ – things that are beyond the possible.

If traditional predictive or explanatory models are detective stories, revealing at the end ‘whodunit’, then scenaric models are romances, exploring possibilities, revealing unexpected intricacies. They are sustained by their links to the real world, and also inform it, but, in their focus on the possible rather than the contingent, they are a wholly richer enterprise.

Thus we need to read scenaric models differently. We need to treat them as helpful lies, whereas we might treat predictive or explanatory models as unhelpful truths.

Almost the first thing we should do with such model outputs is to disbelieve them. But we should do this with the results of any scientific enterprise, since science thrives on and depends on scepticism. This proper posture of disbelief is not to be confused with our pursuit of understanding that emerges from it. We should examine the results to find the source of our disbelief – that is, we should look for surprises. What unexpected things emerged from the analysis? How did this or that surprise arise, given our prior knowledge of the system?

Then we should check the results against those of other studies. In the present case, this is one of the most important things we need to do, but we need to do it carefully. Each of the major components of the model will have equivalent ‘single issue’ studies against which they may be compared. We need to be mindful of the strictures discussed above about the relationship between the multidisciplinary and single discipline studies, and keep our checks and comparisons at a suitably high level. Thus we need to ask ‘Does the broad thrust of some component of the model accord with the broad understanding within the discipline?’ rather than ‘Do the nuts and bolts of this component of the model match the nuts and bolts of the standard disciplinary model?’

Finally, we should look for deeper links in the system. The surprises we find in the results are due as much to our inability to imagine the (non-linear) consequences of the relationships that we have faithfully described in the model as to the emergence of truly novel phenomena. With the wisdom of

hindsight, we can now track back our surprises to their sources, and examine the ways in which the links and relationships allow the propagation of surprises through the system. The use of different scenarios may help significantly in revealing these tracks, since the scenarios each emphasise different forces in the model.

## **The modelling traditions in the natural and social sciences**

It used to be a sort of ‘Sydney or the bush’ thing, scientific modelling. It could be like physics, proper and grand, or it could be a less reputable activity altogether, hardly worth considering as real science. Respectability in science, for many new scientific disciplines struggling for respectability, has usually been measured by closeness to physics, or at least adherence to its mores. Thus we see in the emergence of the three main disciplines represented in the report – the natural science discipline of ecology, and the social sciences of economics and demography – an adherence to the physics of the time of their emergence. The neo-classical synthesis in economics depends on a mathematics and world-view of 19<sup>th</sup> century physics (Reder, 1999), just as surely as the demographic transition theory of demography (Lutz, 1996) or trophodynamics of ecology (Bradbury et al., 1996) depends on an early 20<sup>th</sup> century physics.

In this sense the modelling traditions in the natural and social sciences of the report are more alike than they might realise. They share some implicit assumptions about how to do scientific modelling: it should be informed by theory (how the world should be), it should be describable in a mathematics that stresses linearity and equilibrium (sets of differential equations, usually), and it should be predictive or explanatory. Whether the mathematics harks back to Newton as in much of economics, or uses post-Einstein work as in some ecology, the message is the same.

It is not our intention here to argue the merits of this sort of modelling within any of these disciplines, even as we acknowledge that even physics has moved on in its own approach to modelling, no longer asserting the primacy of theory in all cases (Wolfram 1984). Instead, we note that modelling approaches that work well within a discipline may not work at all well in a multidisciplinary context. By far the best example of both hubris and naiveté has been the Club of Rome program (Meadows et al., 1972), which sought to apply the common modelling approach of the economics and ecology of the 1950s to the multidisciplinary problem of the interaction of the human population and its environment. The failure of that program, in terms of furthering our scientific understanding of the problem, is due in no small part to the naïve adoption of a theory-bound modelling approach.

The empiric approach of the CSIRO report, then, has much to commend it in the present circumstances. It sits to one side of the mainstream modelling tradition in both the natural and social sciences. That is a strength rather than a weakness, since that tradition makes an (often implicit) assumption of theory, and at our present level of understanding of the larger problem, we are in advance of a comprehensive theory. The CSIRO approach allows us to push forward the frontier of our understanding of the problem, and gives space for theory to grow up behind it. It allows us to get on with the job.

## **The problem of sustainable development**

If there is a ‘theory of everything’ underlying the multidisciplinary problems addressed by the report, it may well be found in the ideas of sustainable development. These ideas have exercised the minds of policy makers and the public for the last decade or so, and have firmly entrenched themselves in the public policy agenda of all developed countries. They seek to reconcile environmental, social and economic concerns, so they are explicitly multidisciplinary. They also seek a global perspective, so are explicitly systems-oriented. They try to articulate a coherent argument about the interdependence

of environmental, social and economic concerns, so they are a precursor to a theory. But it is not a theory (or not yet) in a scientifically accepted sense. It is more an intellectual scaffolding that could support the construction of theory.

The empiric modelling work reported here then has an unusual, but potentially enormously productive, relationship with the ideas of sustainable development. To understand this, we need to understand a little more deeply, the depth of the failure of the Club of Rome program discussed above. This work preceded the formalisation of the central ideas of sustainable development, and was implicitly and rigidly theory-bound in a modelling formalism called system dynamics. Hence it has been unable to contribute effectively to the evolution of sustainable development ideas that necessarily go into 'soft' areas where system dynamics fears to tread. It has also been unable to benefit from the continuing evolution of those ideas that are seeing a progressive merging of soft and hard sciences.

The CSIRO work is able to contribute directly to the development of a theory of sustainable development. Its scenario results yield statements that have meaning across the full spectrum of thinking on sustainable development, since they do not presuppose an underlying theory. Conversely, the work can be informed by sustainable development thinking in an unconstrained way. It has no theory to be defended at all costs, and so its results can stand the test of time, and are worthy of progressive reinterpretation in the light of unfolding theory.

Much more than any theory-bound approach, the CSIRO modelling is the precisely right partner to today's sustainable development thinking. It can be seen as catalysing rather than inhibiting the emergence of the new ideas that will be essential if we are to construct a coherent theory and robust policy for sustainable development.

## ***CRITIQUE***

### **Are there 'issue' sub-models with counterpart 'disciplinary' models?**

As an approach, the 'design framework' modelling protocol is not focussed on any particular discipline (Gault et al., 1987). It is not peculiarly economic, ecological, demographic or whatever. Nor is it focussed on any particular level of problem. It makes no difference if the problem is within some small bit of the economy, an entire ecosystem or the world's whole human population. It is an entirely generic construction, and is given its meaning by the problem under attack.

It is also naturally hierarchical. We may think of each calculator as a model of some bit of the system in its own right – as a sub-model. Thus we might expect to find calculators that represent disciplines, that there might be an economic calculator and a technology calculator and so on.

This is only partly true, but mostly untrue. The world is not really divisible into non-overlapping bits called disciplines. Even the sectoral workshops referred to in the report that preceded the model-building are highly multidisciplinary. Where it is partly true – that is, where a calculator is mostly concerned with the problems of one discipline – we may compare the sorts of results the calculator produces with the sorts of results that a standard disciplinary model produces.

We see this best in the population area. The five demography calculators together generate population projections. While the way in which each of these calculators works might not mimic exactly the standard processes of the discipline of demography, the results should at least be directly comparable. It is comforting to find, as described in the report's appendices, that the population calculators not only 'hindcast' the Australian population accurately over the last 50 years, but that they produce projections which are in very close agreement with the standard projections produced

by official sources such as the Australian Bureau of Statistics. Where the power of the present approach exerts itself, of course, is in the way that these projections are able to interact intimately with the rest of the model because of the way in which they have been constructed.

However, there is really nowhere else in the model where discipline maps closely to calculator. Areas such as forestry, fisheries or transport are thorough mixtures of disciplines. This can become a problem if the theory underpinning a discipline has no path into the model given the model's focus on an empiric, data-intensive protocol. The very thing that the proponents of the 'design framework' proclaim as a virtue – its empiricism – could then become a vice.

Disciplines are deeply bound with theory, often to the point where the theory is so embedded that it is no longer even recognised as such. Theory is, after all, what gives a discipline its distinctiveness. Economics would be unrecognisable without its general equilibrium theory, ecology has its underpinning of evolutionary theory, and demography, its demographic transition theory. None of these has a place in the model proper, but yet each has an important contribution to make, not only to understanding the immediate problem but also to setting it in a wider context.

But being excluded from the model proper does not mean theory is excluded from the whole framework. Theory intrudes, properly, in the workshops where the relationships among the variables are argued out. For example, the types of growth exhibited by fish and human populations are informed by ecological and demographic theory respectively. Similarly, human demand for food and fibre or the human propensity to substitute one technology for another are informed by economic theory and 'Factor 4' ideas respectively.

Disciplinary theory may also intrude in the part of the framework the modellers call 'control space' – the place where the model is interpreted and decisions start to be made. It is here that disciplines and their theories mix it with the ideas, values and goals of the users of the model. This will be explored further in the next section.

A final caveat is needed however. The fact that the disciplines are mostly smeared out across the model carries a sting in its tail. If there are important aspects of a discipline that are not adequately accounted for in the model, then the model is weakened systemically. We will consider this issue in the sections that follow.

## **How are the soft systems joined to the hard systems, and what can we say about it?**

We argued above that disciplines are spread across the model's components to the point that there is not a one-to-one correspondence of discipline to calculator. And we have also argued that the modellers see as a strength their focus on the material world, the thing they call the physical economy. Together these two parts of the protocol create problems for the soft sciences – the sciences concerned with the non-material, such as human behaviour or human ideas.

We might expect that a solution to the problem might be to locate the soft sciences (such as political science and sociology) in the control space of the framework where the users observe and control the model. Then we would locate the hard sciences (physics, biology, geology and so on) in the machine space where they would describe the material world or physical economy. We could then say that all the sciences are joined within the design framework.

But this is not a complete solution. Some sciences straddle the boundary between hard and soft – the distinction is not at all clear. The problem is most acute with economics, since it is the most chimeric of the sciences, with both hard and soft tightly entwined. In its use of reasonably sophisticated

mathematics and empirical data, it looks like a hard science. In its reliance on behavioural processes in the dynamics of markets, and its existence in ideological flavours – market economics, Marxist economics, political economy – it looks decidedly soft.

Clearly, disciplines like economics need to be able to find homes in both the control space and the machine space. If the framework is faithfully representing economic phenomena and at least acknowledging economic theory, we should expect to find evidence of the harder parts of economic thinking in the machine space and the softer parts in the control space.

To a large extent, this is what we find when we examine the framework. We find, for example, a neat conjunction between the hard economics of national accounting (Leontief, 1966) and the ideas of embodied energy and embodied water. They each use a highly empirical data system, and rely on notions of balanced accounts to reveal their dynamics. This conjunction goes even further, allowing national accounts data to be used to create embodied energy accounts.

But we do not find Adam Smith's invisible hand in the model proper. We do not find, in fact, market behaviour – the automatic adjustments between supply and demand through the price mechanism. Nor should we expect to, since these are not material processes. We must seek for such soft dynamics in the control space.

The control space is where tensions or dilemmas are resolved and it is here that soft dynamics like market behaviour are revealed in the ways in which users respond to the dilemmas and rework the model.

### **How is 'the physical economy' distinguished from 'the (monetary) economy' – or how does economics get a look in?**

With a complex area like economics, as we have just described, the problem is not simply reducible to deciding that this or that should reside in machine space or control space.

The fact that the physical economy does not include prices does not imply that prices are not important. The scenarios provide a physical description of transactions in possible future economies. If those transactions come to pass it will be because, in some sense, people choose them. There may be many reasons for people's choices, but economic conditions as reflected in prices will certainly be among the most important.

The framework omits prices, not because they are not important, but because of the timescale and scope of its concerns. The empirical base for economics (and related behavioural sciences) is observed behaviour under current conditions. Its theories are based on the choices people are observed to have made, and are summarised in parameters such as elasticities of various kinds. This may be a sound basis for predicting the consequences of small changes from the status quo, but it provides little guidance if we are concerned with the possibility of major structural changes when choice sets or even the psychological bases of preference may differ.

Future developments will be the result of people's (dynamically changing) preferences and the physical world in which those preferences are expressed. Whatever the merits of economics (and related behavioural sciences) for predicting short-term marginal developments about the status quo, it provides no basis for long-term predictions of substantial dynamic change. We just do not, and cannot, know the future elasticities. That is why ideas of the scenario and the control space are so important: they allow for the choice component to be guided as much as possible by actual human input (consultation, discussion, workshops – all the social activity in 'control space').

On the other hand, we do know a fair bit about the physical world. There is a wealth of scientific, engineering (and economic) information about energy efficiencies, material intensities, crop yields, consumption patterns, labour productivities, and so on. These can change, but the changes are bounded. Existing technologies can be improved, but the improvements are subject to saturation (as will be discussed below). Radically new technologies may be introduced, but they cannot come in overnight. New infrastructures need to be provided and, while they build up (absorbing resources) old infrastructures need to be maintained to 'keep the show on the road'. Evaluation of such scenarios in physical terms is the first step in identifying directions for sustainability policy.

But there is no question that the implementation of such policies will need to take account of – and manipulate – the prices of goods and resources.

### **An economic modeller's perspective**

In *Future Dilemmas*, Barney Foran and Franzi Poldy of the CSIRO conduct an exercise in assessing alternative migration policies. They feed three alternative assumptions about future migration policy into a complex model to generate three scenarios for Australia to 2050. The reader is invited to compare the three scenarios to make judgements about which migration policy best serves the national interest.

The contribution of such work can be assessed by comparing it with related work that is already in the public domain. In the early 1990s in a consultancy for a bureau of the immigration department, Econtech developed a system for assessing the economic effects of alternative migration policies. Alternative migration scenarios are fed into a demographic model which in turn generates inputs for a widely-used model of the Australian economy known as MM2. This system has been used often, its most recent use being earlier this year.

In this most recent analysis, Econtech used the system to estimate the economic impacts on Australia of the 2002/03 migration program for the immigration department. These economic impacts were relative to a baseline scenario in which the 1995/96 migration program continued without change.

The economic impacts for 2007/08 were as follows:

- a net addition to the total population of 0.29 per cent or 60,000 people;
- an addition to the population of working-age (15-64 years) of 0.89 per cent or 126,000 people (the populations for the younger and older age groups were lower);
- a gain in labour force participation of 0.71 per cent;
- a gain in annual funds transferred to Australia by migrants of about \$1.7 billion;
- a gain in the skill level of the Australian workforce of 0.24 per cent;
- a gain in GDP per head of 1.15 per cent; and
- a gain in annual consumption per head of 1.22 per cent or \$344.

The most important result is the bottom line for Australian living standards, as measured by consumption per head. The significant gain in living standards of 1.22 per cent reflected the following policy developments in the 2002/03 program compared with the 1995/96 program:

- the capping of the parent component of the family stream, making the migrant intake younger;
- the shift since 1995/96 in the composition of the migration program from the family stream to the skill stream; and
- measures taken to improve the skill level of components of the skill stream.

These results confirm that the various changes in migration policy are likely to yield an economic dividend. They also provide ballpark estimates of the amount of that dividend taking into account an extensive set of linkages from demographic to economic outcomes. It is interesting to compare this Econtech analysis with the CSIRO analysis.

The CSIRO modelling only provides estimates of the first three of the seven economic impacts listed above. These cover demographic and labour force outcomes, which rely on relatively simple mechanical modelling. The remaining four economic outcomes are not covered by the CSIRO model, reflecting the simple nature of its economic component. The lack of any recognised summary measure of the net economic benefit of alternative migration policies, such as the effect on GDP or consumption per head, is the first limitation of using the CSIRO model to assess migration or other policies.

Similarly the CSIRO model does not capture the effects of the migration policy developments that affect the average skill level and wealth of migrants, neither of which appear as variables in the CSIRO model. So a second limitation of the CSIRO model is that it cannot be reliably used to assess the impact of changes to the composition of the migration program.

Indeed, Foran and Poldy appear to realise this and instead focus on the impact of changes in the level of migration, in the three scenarios referred to at the outset of this note. In three scenarios, annual net immigration is varied from zero to 70,000 to 0.67% of existing population.

However, even this approach raises problems. The economic effects on Australia of these changes to the level of the migration program are quite different depending on the balance of the program between migrants with high economic attributes (young, wealthy, high-skilled) and low economic attributes. For example, this balance has changed to an important extent since 1995/96, as demonstrated by the Econtech economic modelling described above. Foran and Poldy do not explain what this may mean for their results.

The CSIRO model includes a standard demographic model based on the cohort-component method, as well as physical relationships which are better assessed by scientists rather than economists such as myself.

The economic component of the model is simple. Everything is measured in physical quantities such as kilograms, joules and litres, leading the authors to describe it as a model of the 'physical economy'. Production and consumption decisions are assumed to be based on simple physical relationships. It is a mistake to believe that such an approach avoids reliance on economic theory. Rather, it assumes that decisions by consumers and businesses are not systematically affected by prices and costs, when there is a mountain of empirical evidence to the contrary. Indeed, prices do not even appear in the CSIRO model, even though they play a fundamental role in balancing supply and demand right across a market economy such as that of Australia. This is a third limitation of the CSIRO model.

The suggestion that modelling the 'physical economy' is a novel or new idea is incorrect. In fact it is a form of the input-output method that was set out far more comprehensively by Wassily Leontief in his 1941 book on 'The Structure of the American Economy'. In the last 60 years this strand of economy-wide modelling has developed considerably to cover prices, and to allow for the price-sensitive nature of decisions by consumers and businesses (in CGE models), but Foran and Poldy have not taken on board these important developments.

One potential contribution of the CSIRO modelling is in addressing the issue of possible economies and diseconomies of scale from expansion of the Australian economy. Econtech's modelling does not address this difficult topic, but rather takes a neutral position on the basis that one can point to economies of scale in some areas (e.g. communications networks) and diseconomies in other areas (e.g. a fragile natural environment that can be degraded by economic activity).

Both economies and diseconomies of scale need to be considered as part of any balanced consideration of the issue of economies/diseconomies of scale. Indeed, one reason for Australia's large-scale post-war migration program was a belief that there was a need to boost Australia's population to generate a local market that was large enough to take advantage of economies of scale for a manufacturing industry that was protected from import competition.

Foran and Poldy ignore economies of scale, including in communications networks, and instead focus purely on diseconomies of scale. This exclusive focus on diseconomies of scale loads the deck against the migration program and is a fourth limitation of the CSIRO model.

Foran and Poldy focus both on depletion of reserves of natural resources such as natural gas and oil, as well as degradation of water, air and land quality.

Their focus on reserves of natural resources recalls the Club of Rome projections of thirty years ago. One accurate projection of the Club of Rome was that the population of the world would be around 6 billion at the turn of the century. Most projections of what this would mean, especially for reserves of natural resources, were completely astray.

World reserves of natural gas were projected to be exhausted about 10 year ago and reserves of aluminium about now. This led Paul Ehrlich to contend that prices of many natural resources would skyrocket. Julian Simon challenged this and bet that any \$1000 shopping basket of raw materials of Ehrlich's choosing would be less expensive by 1990. The loser was to pay the winner the difference. In 1990 Ehrlich had to pay Simon \$576.01.

What has happened before the Club of Rome produced its projections and has happened since is that real prices of natural resources have tended to fall. When scarcity has threatened, the resulting price rises have stimulated more efficient use of the resource as well as increased exploration leading to increases in proven reserves. Further, continuing improvements in mineral exploration and extraction technology have kept real prices low.

The CSIRO model does not include prices and therefore is missing the main feedback mechanisms whereby, through price rises, an emerging scarcity of reserves can be overcome through increased exploration activity and more efficient resource use. This omission leads to unduly pessimistic projections of Australian reserves, which is a fifth limitation of the CSIRO model.

In any case, given that natural resources such as gas and oil are tradeable, the more important issue is world reserves, not the Australian reserves that are tracked in the CSIRO model. The assumed changes in migration flows from other countries to Australia will not greatly impact on world reserves of gas and oil, since people will consume from these reserves wherever they live, although possibly at different rates.

The same point holds for Foran and Poldy's modelling of a connection between Australia's migration program and Australian greenhouse gas emissions. Greenhouse gas emissions are a global issue, and so in modelling the migration program one should only take into account the net difference in emissions from someone living in Australia rather than another country. Foran and Poldy do not do this, which is a sixth limitation of their model.

The more interesting side of the CSIRO model is in its modelling of urban air quality, water quality and land quality. However, again it is a stretch to view these environmental issues as being mainly the concern of migration policy.

Foran and Poldy generate their scenarios based on the possible extremes of net migration. More realistic scenarios for annual net migration would be 60, 90 or 120 thousand leading to an Australian population in 2050 of 24, 26 or 28 million. These fairly narrow variations in population outcomes would lead to similarly narrow variations in environmental outcomes.

Of much greater consequence for environmental outcomes are environmental policies themselves. For example, the shift to lead free petrol and the looming shift to clean diesel have major implications for urban air quality. Examining these sorts of issues is where one might expect the CSIRO model to come into its own.

However, where environmental policies are market based, as is increasingly the case, the CSIRO model is again not much help, which is a seventh limitation of the CSIRO model. A model that omits prices, and consumer and producer responses to price changes, cannot contribute much to analysis of the effects of policies that operate by raising prices where there are negative externalities and reducing prices where there are positive externalities.

At a broader level, the population debate is always evolving and increasingly is focussing on emerging problems for developed countries arising from prolonged low fertility. While the collapse in fertility maintained since the 1970s is no doubt primarily due to the introduction of the contraceptive pill and the feminisation of the workforce, the false alarms of the Club of Rome, with its claim that responsible couples should limit themselves to two children, is no doubt an unwanted contributor.

Developed countries now have to develop policies to deal with populations that are projected to age rapidly in the next few decades and then start declining. This shift in policy focus may make the CSIRO model, with its negative message about population and economic activity, increasingly less relevant.

As members of the External Reference Group, fellow economist Professor Mark Wooden and I have made these points throughout the course of the project but note that the current CSIRO model is currently unable to incorporate the economic perspective as outlined above. This area of research straddles the physical and social sciences, and the obvious way to address the seven limitations of the CSIRO model that are identified in this note would be a multi-disciplinary approach in which physical and social scientists work side-by-side. Such an approach has already been followed elsewhere in modelling policies affecting global greenhouse gas emissions.

Chris Murphy  
Mark Wooden

## **Creating the link between people and their environment – or how does demography get a look in?**

Our discussions above about ‘issue’ sub-models and the problems of joining soft systems to hard systems describe to some extent how demography is treated in the framework. It remains here to consolidate that argument with particular reference to demography.

A useful place to start is to note that the whole framework is an extension of demographic thinking, since it is based on the idea that the purpose of economic activity is to meet the needs (and wants) of people. People need houses, food, transport, and so on. Houses require bricks, timber, glass, and so forth. Food implies crops, animals, tractors, etc. As we unfold this logic, we eventually get to land degradation, water consumption, pollution, resource depletion, and other mainstays of the sustainable development debate. Thus the framework has clear physical links and a direction in which we do all the accounting.

But demography is more than accounting identities and projection models, which are essentially simple arithmetic constructions. It also includes understanding and explaining the values of fertility, mortality and so on. In other words, like all disciplines, it is embedded in theory, such as demographic transition theory. This aspect of the discipline describes choice and behaviour, which are left in control space along with similar parts of economics and sociology - i.e. the values are set exogenously after consultation – or instruction – from the client.

Similarly, the feedback link from the environment to fertility and mortality is in control space and is not modelled.

## **How does the model deal with the essentially spatial notions implicit in the concepts of sustainable development – or how does ecology get a look in?**

There are two traditions in ecology that might be drawn into the framework (Bradbury et al., 1996). In the event, only one really is. In this section we will examine if this is a reasonable thing to do.

The first, and oldest, tradition is that of natural history leavened with the theory of evolution (Hutchinson, 1965) and is called population dynamics. It talks about populations of organisms and their distribution in space. It is concerned with the origins, lives and fates of individuals and populations. It is also intensely interested in how the higher structures of the natural world – communities and ecosystems – emerge from the lower structures – individuals and populations – through ecological interactions – predation, competition and symbiosis – and how these structures then become evolutionarily coercive. We might call this the biodiversity view.

The second tradition is called trophodynamics (Morowitz, 1968). It looks at the problems of ecology from the point of view of flows of materials and energy. It has always been intimately associated with systems analytic approaches to biology and provides powerful descriptions of ecosystems as systems of stocks and flows. But it has a major drawback in that it does not recognise the primary locus of evolutionary action – the species – and so finds it hard to provide an evolutionary perspective. We might call this, in contrast, the biomass view.

It does not really matter in a trophodynamics analysis that the entities have an evolutionary history, while it is the thing that matters most in a population dynamics analysis.

Population dynamics is very similar to much human demographic analysis. Indeed, some of the first mathematical formulations of population growth were used in both ecology and demography with great effect (Pearl, 1925). So we might expect the model to use population dynamics calculators in its ecological parts – agriculture, fisheries and forestry – just as it has used demography calculators in its human population parts. That this is not so is due to the biodiversity problem: while it is feasible to calculate the population dynamics for one species – *Homo sapiens* – for which we have a lot of life history data, it is not feasible to do such calculations for each of the thousands of species in any real ecosystem for which we have very little data.

The model thus resorts to a trophodynamics approach, not so much because of its implicit stocks and flows structure, but because it is aggregated in a way that allows us to make progress. It is not a pure trophodynamics approach however. We see, in the equations that govern the growth of the stocks, echoes of population dynamics equations.

The thing we do not see, and the thing that has the potential to reduce our understanding of the contribution of biology to the model, is the spatial graininess or heterogeneity of the biological processes. The aggregation of species and the focus on biomass that are direct consequence of making the model tractable (rather than being consequences of the approach) reduce perforce the heterogeneity that is both a feature of the ecosystem and an important factor in its dynamics. That factor is lost to us.

To the extent that sustainable development is about the harmonisation of the biophysical systems of the natural world with the socio-economic structures of man, then it is about processes and structures operating at various spatial and temporal scales. Spatiality is thus as important as dynamics for our understanding. If spatiality is to be reinserted as a coercive factor with the dynamics in the system, it must be done somehow in the control space.

### **The spatial dimension**

Australia is a country of continental dimensions and its metropolitan-hinterland relationships of the traditional kind have spread over hundreds of linear kilometres in each direction within the country in the case of each mainland state capital city.

The climatic variations and biotic and soil condition contrasts on a continental scale and from the deep interior of each state to the coasts mean that there are major environmental gradations and variations.

Considering metropolitan and non-metropolitan spatial entities is not really sufficient for understanding the nature of likely human and economic impacts on this great diversity of environments. For instance, in considering the “ecological footprints” of large cities, are the impacts greater where there has been migration away from the cities to the coastal zones- particularly the belt south from Hervey Bay in Queensland to the Bass Strait coast in Victoria, coastal areas southeast of Adelaide and the south west of Western Australia?

Are the environmental impacts worse in the relatively more watered non-metropolitan coastal areas, or in inland dry zone farming areas, in semi -arid grazing areas or in deserts- the inland areas being far less populated by humans? Is the nature of the material economy fundamentally different between the metropolis, the high amenity non-metropolitan coastal areas or the inland? Does the lateral expansion of the metropolis create more environmental damage than other forms of urbanisation and consumption in the coastal zone?

To answer these and related questions, analytical modelling of the multi-regional kind should be undertaken, with at least the following components: the metropolis and its perimetropolitan zone; urbanising areas in other parts of coastal Australia, and changes in inland areas. That is, a minimum of a three region model for each state, and taking account of the eccentric locations and their possible differential impacts of some cities like Brisbane. Such modelling should include stocks and flows, and alternating growth scenarios within each type of region.

Ian Burnley

### **How does the model deal with innovation and change, both technological and social – or how does ‘Factor 4’ thinking get a look in?**

As much as everyone agrees that scientific breakthroughs and technological innovation are major drivers of societal change, no one has a good theoretical basis for predicting either the long-term direction of science and technology or its impact on society. Almost the opposite is the case, with eminent scientists and technologists like Lord Kelvin and Thomas Watson making spectacularly wrong predictions about the fate of the solar system and the need for computers respectively. For deep reasons to do with the nature of complex systems, we just cannot pick winners in science and technology.

The CSIRO modellers rightly avoid such traps. However, there is a sense that short-term incremental change can be brought within the scope of the project. One way to do this is to develop scenarios that mimic the potential impact of so-called ‘Factor 4’ technologies (von Weizsacker et al. 1997). This is essentially a call for a new set of technologies. Because the inputs and outputs of these technologies are specified – broadly half the resources as inputs, with twice the efficiency of processing resulting in quadrupled outputs – even if we do not know what the technologies actually are, they can be incorporated into the framework as a feasible scenario, after making some further assumptions to ensure that they are scientifically ‘lawful’.

Thus the framework can do useful work to decide, in the first place, if various Factor 4 strategies are feasible, and then, if so, it can work through the consequences of such technologies for the whole framework as for any other scenario, by creating and exploring dilemmas. And, as with the other scenarios, resolving the dilemmas, deciding whether or not to embrace Factor 4 or other innovation strategies, and developing public policy to introduce the innovations are all activities to be handled in control space.

There are a vast number of possible permutations and combinations of different feasible Factor 4 technologies in such a well-specified framework as the present one. The CSIRO modellers have

wisely chosen to describe the potential for using the framework in this way through only a few examples. They describe the consequences for the whole framework of halving the material and energy inputs to a group of important components in construction and transport – broadly, the manufacture and maintenance of buildings and vehicles.

However, we need to keep clear in our minds that the projection of these incremental, short-term changes, even if carried out over long time scales, is not the same as predicting the impact of future scientific and technological innovation on society. These future innovations will undoubtedly create dilemmas for society that, in their novelty, are unaccounted for in anyone's scenarios.

### **A technology analyst's perspective**

Management of flows, through appropriate policy formulation, will clearly remain a critical area for government attention and action. In fact the positive environmental effects of reducing the energy and materials intensity of the economy, demonstrated by the two sub-scenarios in the study (buildings and transport) will probably drive government towards a policy stance of 'architect' rather than 'observer'.

However, even if this is not driven by local community concern and public values, it seems bound to be an outcome of economic survival in a global market. Many of Australia's trading partners in the OECD are taking a much more interventionist approach to industry and environmental policy, seeking to stimulate infrastructural change and technical innovation, to de-link economic growth from resource consumption. In these countries, combinations of resource taxes, procurement programs, targeted public R&D funds, information systems, standards and regulations, are being used to stimulate a progressive dematerialisation of production and consumption.

New systems of pollution and waste prevention, eco-products and services, and intelligent transport logistics and distribution systems, are the intended outcomes of such a policy framework, which assumes that it is possible to achieve 'win-win' economic and environmental outcomes through innovation. Resource efficient goods and services are seen as critical to reducing 'over-consumption' in developed countries (the Rio and Johannesburg agreements) and for development in countries which are resource and infrastructure poor.

Government attention to effectively managing resource flows (in the EU for example), has seen the growth of research organisations able to model the resource economy and support policy formulation by life-cycle thinking. The result of this shift in thinking is evident in the submissions from international business organisations to the World Summit for Sustainable Development in August 2002. In the face of such hand-on (industry and government) management approaches, a hands off 'leave it to the market' stance would simply run the risk that the Australian economy, infrastructure and technical development, would settle into a backwater, increasingly isolated from the new dynamics of the global economy.

Chris Ryan

## *CONCLUSION*

### **What emerges from the study?**

A key argument for modelling the whole system rather than its parts is that it is supposed to reveal something more than what is revealed by a set of models of the parts – the whole is believed to be more than the sum of the parts. Thus ‘whole system’ modellers look for ‘emergence’ – the generation of processes and structures that would not be seen at the level of partial models (Holland, 1998).

But what is the whole we wish to consider? Any reading of the CSIRO study confirms that the model itself is always seen in a larger context. There is a strong sense that the stakeholder workshops are an integral part of the process. There is also a sense that the model’s users are also part of a whole system. This last point is made quite forcefully in the overall modelling strategy – the model (in the narrow sense) produces dilemmas or tensions that cannot be resolved within it. Instead, we seek resolution in a more embracing context where the users of the model – such as policy makers – can offer potential solutions whose efficacy can then be examined within the model. Thus, users and model are in a feedback loop, and together form a larger system out of which we might expect ‘emergent behaviours’.

In a sense, users and model now become partners in a broader endeavour, and their previous roles as, respectively, subject and object become blurred. The boundaries between them are open, as are the boundaries between the disciplines within the model itself (Sherman and Schultz 1998). This openness is one of the particular strengths of the approach.

Thus, it is with this larger idea of emergence that we make our observations.

Perhaps the most striking, and first, thing to emerge from the study is the sheer diversity and intricacy of the interactions that make up the whole system. When viewed as a whole, and informed by the tremendously detailed workshop reports, we see a new picture of Australia, one in which there is both ‘devil in the detail’ and some long-term strong processes driving the system. We see primary, secondary, tertiary and quaternary drivers – some direct, some indirect, some immediate, some greatly lagged – influencing the system of the human population and its environment.

This complexity just cannot be seen with single-issue models, and so this feature alone is a strong justification for the approach, even in the absence of more detailed analysis. It can be used as a reality check for disciplinary models, helping them acknowledge the richer world in which they exist.

However the richness of the system has greater uses than this. It is the primary source of a new understanding of the system being revealed by the study.

The study shows that we need to understand and manage both the stocks and the flows in the system, but that, by and large, we traditionally tend to focus on the flows. Stocks, as extremely slow moving variables in the system, may seem to be us, with our short time horizons, to be constants in the system, in contrast to the fast moving flows. But stocks have tremendous potential to modulate system behaviour over the longer haul, and indeed, drive the system in unexpected and sometimes undesirable directions. We see this in the present study in the way technology can ‘saturate’, resulting in environmental variables coming to drive some outcomes, and in the knock-on effects of resource stocks becoming constrained.

This attention to stocks as well as flows provides both a rationale for an expanded role for public policy and a setting within which the resulting tensions or dilemmas may be handled.

The distinction, in the study, between stocks and flows mirrors a distinction in our society between the concerns of public policy and the market. There is a sense in which the management of flows – fast moving variables in the system – is one of the key concerns of the market economy. There is also a recognition by government that it should get out of the business of the management of flows and ‘leave it to the market’. This is reinforced if one observes that, in recent years, government has not only deregulated many of the markets it once managed (electricity, water, dairy and so on), it has also attempted to create new (deregulated) markets for previously unregulated and unexploited flows (carbon credits, salinity credits and so on).

The CSIRO report implicitly suggests and justifies a new role for public policy, even as public policy passes the management of flows to the market. This new role is the management of stocks, and this discovery is the second key thing to emerge from the study. The study shows emphatically that the stocks have time scales of decades or centuries, far beyond the concerns of the market, but it also shows that the management of stocks is as important, and probably more important than managing flows in resolving the dilemmas generated by the model.

The existence of the dilemmas is the last important feature to emerge from the study. The report identifies six dilemmas that cannot be resolved within the model. They each require policy intervention. Each of the dilemmas is important, involving major components of the system, and having strong effects on the behaviour of the whole system. The report shows that, while it may be possible to solve any single dilemma with concerted national action over a generation or two, in reality solutions will need to be sought for more than one dilemma at a time. Because dilemmas interact, the complexity of the problem will grow as more dilemmas are considered. The report offers no solution to this problem, instead only identifying it, and noting the importance of a whole-system approach to deeper understanding. It also notes that public debate is required to further bound the range of each dilemma.

### **Are the report’s conclusions robust?**

We need to consider two different aspects of robustness in examining this issue. The first has to do with the structure of the model itself – its grounding in physical reality, and its superstructure of progressively ‘softer’ sciences – with attendant questions about the robustness of the different components and their dependence on different disciplines with different conceptions of robustness. The second has to do with the use of the model to generate scenarios – with attendant questions about the robustness of the scenarios.

We may conceive of the model more or less as a hierarchy of calculators, each itself a model of some particular bit of the system. But we should not confuse this hierarchy with the implied scientific hierarchy above of natural sciences through to social sciences. In the individual calculators, soft and hard sciences are mixed up. Depending on the purpose of a calculator, it may derive its data and relationships from several disciplines.

Despite this mix of hard and soft science, three features of the modelling protocol ensure a high level of scientific rigour. In the first place, the whole model is highly empiric. It is based on actual data and known relationships over a long ‘training set’, which in the present case is the last 50 years. The model is grounded in this ‘training set’ by ‘hindcasting’: key individual calculators are progressively tuned and refined until they are able to ‘predict’ the known history accurately. Secondly, the model seeks to represent ‘only’ physical reality, for which the modellers use the term ‘the physical economy’. This means that they only accept into the model those variables and processes that can be

represented scientifically – they must be able to be measured in standard SI units – and hence are part of the real or material world. This is not to say that non-material variables, such as money, are not important to the way the world works. It argues instead that, because such non-material variables, if they are important, would have effects in the physical economy, their effects can be represented appropriately in the model. The last feature of the modelling protocol contributing to rigour is its ‘lawfulness’: the relationships between the variables follow known scientific laws. Thus, for example, matter and energy are conserved as required by physical law, and calculators may only interact in lawful and not arbitrary ways.

The effect of this rigour permeates the whole model and allows us to say that, if we accept that the calculators have captured the physical reality of their part of the world, then we should accept that the results the calculators produce will represent the path that their part of the world will take. The degree to which this is not true will be due solely to the degree to which we have not captured the physical reality and not to any other extraneous factor, such as the adequacy of any underlying theory. Empirical, physical modelling thus comes with an important intrinsic source of rigour: the ‘truth’ of the model comes from only one source – the data – and it is a source that may be progressively and rationally refined.

We may conclude that, as a modelling protocol, the CSIRO study is highly robust.

The matter of the use of that protocol for the development of scenarios demands its own analysis, even though the present study tends to confound them by assuming that the protocol is usually used for scenario work.

We have discussed above the important differences between predictions and scenarios. And it is in the light of these differences that these comments on the robustness of the scenarios need to be understood. The two key points that bear on such robustness are the existence of dilemmas and their nature.

The first point is easy: dilemmas or tensions manifestly exist in the real world. It is our common human experience that issues continually arise within a frame of reference that can only be resolved by resort to a larger, more embracing frame of reference. This is a fundamental feature of all complex systems from social systems to mathematics (Gödel, 1931). It gives us some comfort that the study generates dilemmas. Indeed, it would be alarming if it did not. In this sense, the study is robust.

The nature of the dilemmas is trickier. The actual dilemmas arise in the model as a consequence of the working through of the scenarios, and we have argued that the scenarios should not be held to be true, in the sense that we expect explanations or predictions to be true. We ask no more of the scenarios than that they should be plausible and interesting: plausible in the sense of being a story that is continuous with the real ‘story so far’; and interesting in the sense that, of all possible scenarios, the ones we choose have resonance with our concerns. We assume that, given the modelling protocol, scenarios will always be feasible, that is scientifically lawful. So it is not immediately clear how we should judge the robustness of some particular dilemma arising from some scenario.

Perhaps the best we can say is that the scenarios inherit their robustness from the modelling protocol, and the dilemmas inherit theirs from the scenarios. This line of argument leads us to suggest that while a particular dilemma may not be ‘real’, because it is robust and its antecedent scenario is both plausible and robust, then the dilemma surely resides in the neighbourhood of a real dilemma. We would be wise to take it seriously.

## What are the report's implications?

Most research studies conclude with the mantra 'more research is needed'. This is also the case here. But this report offers us more than such an introverted implication. It offers a nested set of implications, deriving from the whole project, the model itself, the scenarios and the dilemmas.

Consideration of the whole project leads to the implication that it is feasible to analyse complex policy problems holistically rather than in a reductionist way. That is, we are not confined to thinking of such complex problems in a compartmentalised way. We are not forced, by a lack of tools or imagination, to analyse, say the demography, the ecology and the economics separately, and later merge them at the policy table in some *ad hoc* integrative way. We may, of course, choose to analyse our complex problems in discrete partitions, but the strong point made by the project is that we are no longer forced to. We have a choice.

An important corollary of this is that the object that goes to the policy table is, in a sense, balanced. The different disciplines make their contributions more or less equally in the policy-neutral and discipline-neutral language of physical reality, and none is 'subservient' to the other.

The model itself reveals that both stocks and flows contribute to the system's behaviour. The strong implication is that we are much better at managing the flows than stocks, in part because of the great difference in their time scales (days and weeks *vs* decades and centuries), in part because we usually think of stocks as a system constant rather than variable, and in part because we have tools to manage flows – the market – but none to manage stocks. We tend to do what we can do.

This implication has an important corollary too: as public policy relinquishes its interest in the direct management of flows (through deregulation and freeing of markets), it should envisage an emerging role in the management of stocks. Government needs to enhance its capacity to have long views of the system.

The scenarios, as argued above, are plausible stories about possible futures. They were chosen because they each represent the particular concerns of different protagonists in the public policy debate on Australia's future population. The model demonstrates that no scenario is an unalloyed good – a clear and unrestricted path to the future. Instead it shows that each creates tensions that need resolution at the policy table. A moment's reflection suggests that this is good common sense – we would be alarmed and suspicious, knowing what we do about the way the world works, if there appeared to be some 'Yellow Brick Road' to the future.

The strong implication of the scenarios is that the future involves dilemmas, no matter which path we take. But the corollary of the implication that there are choices among dilemmas is that we actually have a choice. The future is not determined.

When we consider the dilemmas or tensions, we immediately observe that the system has emergent properties, as discussed above. This observation is not available to disciplinary analysis. This adds to our implication above – the feasibility of holistic analysis – the further implication of its necessity if we wish to understand the whole system. This necessity is compounded when we consider, as discussed in the report, the need to resolve dilemmas in parallel.

The dilemmas create a final implication. While they cannot be more 'real' than the scenarios from which they unfold, they strongly imply the existence of real dilemmas in their neighbourhood, because of the way in which they inherit their 'reality' from the model itself. They merit further research.

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