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A Systems Approach to Analysing the Impacts of Water Policy Reform in the Murray-Darling Basin: a conceptual and analytical framework

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ABSTRACT

The water policy reform under the Murray-Darling Basin (MDB) Plan will have a range of implications for the ecology, the economy and the community of the Basin – given the interdependent nature of the three systems. In this paper, an integrative or a systems approach is proposed to analyse the impacts of water policy reform in the MDB. The first part of the paper focuses on developing a conceptual framework, which identifies the main interdependencies and interactions among the three systems in the MDB. The second part of the paper attempts to operationalize the conceptual framework by identifying the suitable analytical tools or models that link the three systems. The ecology is linked to the economy via the water policy reform, that is, the change in the quantity of water that flows from the ecology to the economy (ecology-economic nexus). The economy is linked to the social system via computable general equilibrium (CGE) and microsimulation models (economy-social/community nexus). Finally, social/community is linked to the ecological system via agent-based models to investigate emergent socio-ecological phenomena. The third part of the paper shows how all the models can be linked in a top down fashion to develop a operational analytical framework, as a starting to point to analyse the macro, sectoral and distributional impacts of the water policy reform in the MDB.

Keywords: Murray-Darling Basin plan, water policy reform, systems approach, distributional analyses, computable general equilibrium, spatial microsimulation, microsimulation

1 INTRODUCTION: WATER POLICY REFORM UNDER THE MURRAY DARLING BASIN PLAN

The reduction in the availability of water caused by the combined impacts of severe drought and water over-allocation to irrigation have brought to the forefront, at least in the last two decades, the public policy debate on the competing demands for water. These are the requirement for environmental flows for the long-term health of the river system in the Murray-Darling Basin (MDB) on the one hand and the sustainability of irrigated agricultural production in the Basin on the other. For example, as early as mid-1992, the then Murray-Darling Basin Ministerial Council initiated the development of an irrigation management strategy with the aim “to achieve an ecologically and environmentally sustainable and self-sufficient irrigation system in the SMDB by 2010” (Hall, et al., p iv, 1994). This water management strategy, articulated two decades ago, remains the overall aim of the Basin Plan (discussed below), which is now under the responsibility of the Murray-Darling Basin Authority (MDBA).

The water policy reform under the Murray-Darling Basin (MDB) Plan[1] aims to achieve two broad objectives: first, to improve and restore the health of the river system in the Basin and second, to encourage farmers to adapt to reduced inputs of water for farming activities. The implementation of the MDB Plan falls under the responsibility of the Murray-Darling Basin Authority (MDBA) specifically created under the Australian Water Act (2007) to manage the water resources in the Basin. The core of the Basin Plan is the attainment of Sustainable Diversion Limits (SDLs), that is, limiting the amount of water that can be diverted to irrigation. SDLs are upper limits on the volume of water that can be taken on a sustainable basis from the Basin's river system. Under the Basin Plan, the SDLs can be achieved in two ways. First, through the Commonwealth buying back permanent water rights from farmers under the water buyback scheme and second, through water-saving infrastructural investment under the infrastructure investment scheme. Under the water buyback scheme, the Commonwealth buys back water entitlements (permanent water rights) from farmers who are willing to sell them on a voluntary basis. This reduces water available for irrigation, thus contributing to a overall SDL target.

Farms are commercial enterprises, and are likely to respond to the reduced inputs of water (and the consequent increase in its price) by, for instance, switching some irrigation activities to dry-land activities, substituting between factors of production, investing in water-saving infrastructure and technology, and so forth. To assist the farmers adapt to the new economic conditions, the second component of the Basin Plan involves the Commonwealth and state investing in water-saving infrastructure investment aimed at increasing the efficiency in water use and technological improvements in farming activities, that is, adopting technologies (input-mix) that minimises water usage per unit of output. One of the important developments achieved in the mid-90s, which may assist farmers in the Basin to adapt more quickly to reduced water availability, is the disentangling of water rights from land rights. Assigning and legally recognising property rights to water facilitated the creation of water markets, thus

[1] A brief background to the Basin Plan is given in Crase (2012).

giving farmers the possibility of trading water intra- and inter-regionally, and since 1998 water trading has been possible between States[2]. The possibility of trading water provides farmers an additional option when determining the optimal allocation of resources in adapting to reduced inputs of water.

The foregoing briefly explained the two main components of the Basin Plan: the water buyback scheme and the water-saving infrastructure investment, to attain the twin objectives of the sustainability of the Basin's river system and agricultural production. In addition, the Basin Plan has further implications. Underlying the health of the MDB river system is the sustainability of the Basin's ecosystem, and thus, the current and future supply of ecosystem services, including the future flow of water for irrigation and other consumptive uses. Similarly, underlying the sustainability of agricultural production in the MDB is the livelihood and well-being of the Basin communities. In this regard, for analytical purposes, the MDB region can be conceptualised as comprising of three broad systems: the economic, the ecological and the social systems. These systems are evidently interdependent and linked in complex ways.

The main aims of this paper are threefold: first, to frame the water policy reform in the context of the three inter-independent and interconnected systems[3]; second, to present an analytical or modelling framework of the MDB; and third, to discuss in detail a modelling framework to analyse the socio-economic and the distributional analysis of the water reform policy. The rest of the paper is organised as follows.

To understand the main interactions between the three systems, section 2 outlines the ecological and the socio-economic significance of Basin region to both the region itself, and to the nation. Section 3 uses a stylised representation of the MDB to elucidate the inter-dependence and the main interactions among the three systems. Section 4 presents the analytical framework to analyse policy reforms in the MDB. Section 5 discusses the environment/ecology-economy nexus within the overall analytical framework, followed by section 6, which discusses the socio-economic nexus, in particular the structural and distributional impacts of policy reforms. Section 7 reviews the Australian experience in linking CGE and microsimulation models for distributional analysis. Section 8 outlines the top down approach to linking a CGE model with microsimulation models to analyse the structural and distributional impacts of the water reform policy under the MDB plan. The final section summarises and concludes the paper.

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[2] Water has been traded in the MDB for years under the state management laws. Assigning property rights to water also made it possible to permanently buy or sell water entitlements/rights.

[3] The rational for a systems and integrated approach to model the ecological, economic and social interactions of policy reforms is well established in sustainable development literature (see for instance, Barbier, 1987; Barbier and Markandya, 2013; Buchholz, 2007; Fiskal 2003 and 2006), and therefore will not be reviewed in this paper in any detail.

2 THE ECOLOGICAL, ECONOMIC AND SOCIAL SIGNIFICANCE OF THE MURRAY-DARLING BASIN

The Murray-Darling Basin is an important regional economy for Australia in terms of its economic, social and environmental significance. The MDB covers an area of over one million square kilometres in south-eastern Australia and occupies about 14 percent of the Australian land mass. The Basin's river system passes through four states and one territory – Queensland, NSW, Victoria, South Australia and ACT (called the Basin states) and eventually flows out to the sea at Goolwa in South Australia. The river system in the MDB includes 3 of the longest rivers in Australia: the Darling (2,740km), Murray (2,530km) and Murrumbidgee (1,690km). The system also includes 23 major rivers in all. The Basin has a diverse landscape – including 77,000 km of rivers and more than 25,000 km^2 of wetlands, which support a wide range of complex ecosystems. The Basin is home to at least 35 endangered species of birds and 16 endangered species of mammals. There are 46 known species of native fish in the waterways of the Basin of which 16 are listed as rare or threatened on state, territory or Commonwealth listings. These statistics underscore the importance of the environment and ecology of the Basin to the Basin itself and to the nation as well.

Agriculture dominates the use of land in the Basin, accounting for nearly 90 million of the Basin's 106 million hectares. The Basin includes 65 percent of Australia's irrigated land. In the MDB, irrigated agriculture is the primary user of water, accounting for over 80 percent of consumptive water use in 2005-06. In 2005-06, the MDB's irrigated agriculture accounted for around 37 percent of the Basin's gross value of agricultural production, 45 percent of Australian irrigated agricultural production and 14 percent of total Australian agricultural production. The volume of water extracted for consumptive use in the Basin increased from around 2,000 GL a year to more than 10,000 GL a year between the early and late 1900s. These statistics show the importance of irrigated agricultural economy in the Basin and to the Australian economy.

The MDB has a population of around 2 million. Almost 40 percent of Australia's farmers reside in the Basin. The size of the MDB economy (Gross Regional Product) is around 8 percent of Australian GDP. The Basin produces around one third of Australia's food supply. Moreover, the Basin produces 53 percent of Australian cereal grown for grains (including 100 percent of rice), 95 percent of oranges, and 54 percent of apples. The Basin also supports 28 percent of nation's cattle herd, 45 percent of sheep, and 62 percent of pigs. The basin accounted for around 10 percent (920,000 people) of total national employment in 2006. Of 920,000 people, around 96,000 were employed in agriculture (around 10.4%), including irrigated and non-irrigated production as well as services to the agriculture sector. These statistics underscore the importance of the Basin's economy not only in terms of its contribution to national output and employment but also to the livelihood and the social fabric of the communities in the Basin.

3 THE THREE SYSTEMS OF THE MURRAY-DARLING BASIN: ECOLOGICAL, ECONOMIC AND SOCIAL

To elucidate the interdependence of and the main interactions among the three systems, a stylised representation of the MDB is shown in Figure 1. Figure 1 is largely self-explanatory. However, several linkages between the systems in the context of water policy reform in the MDB are highlighted. At the top of Figure 1 is the ecosystem or the environment, the core of which is the river system in the MDB.

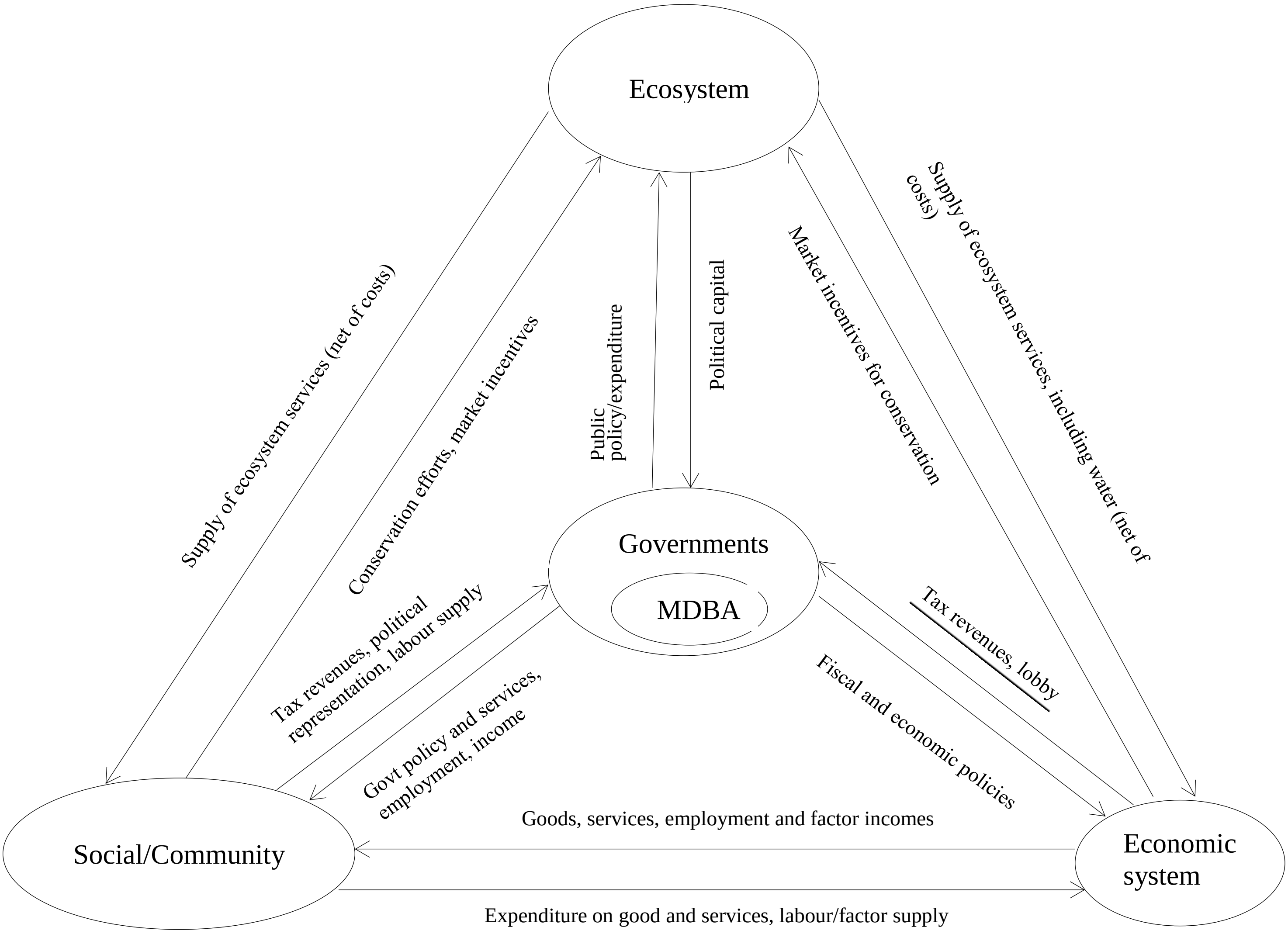


Figure 1: A stylised representation of the interdependence and interactions among the MDB systems.

The ecosystem provides a range of services (for example, water for irrigation and consumptive use, and tourism activities) to the business sector for commercial activities. Likewise, the ecosystem provides a range of services to the community (such as recreation, food and water). Given that an eco-system such as the MDB is largely a public good, it is likely to be over-exploited if not adequately regulated. Thus, a government or public sector is included in Figure

1, to reflect the fact that the Basin region exists and functions within the regional and Commonwealth governments' (including local authorities) overall political and legal framework. That is, the public sector policies and legislations/regulations such as the water policy reform under the Basin Plan affects all the three systems in profound ways. This interaction between Government/MDBA and the ecosystem is largely through expenditure and economic policies, legislation and regulation towards conservation efforts and bio-diversity for long-term sustainability of the ecosystem. Political parties and Governments who care about citizens' concerns about the health and sustainability of the environment and enact sound ecosystem and environmental policies accumulate political capital in the form of constituents' support. The ecosystem-public sector nexus is depicted in the middle part of Figure 1.

Government's policies towards conservation efforts affect the economic system. In terms of water policy reform under the Basin Plan, the key component of which is the reduction in the availability of water for irrigation, this is likely to affect the agricultural and other businesses connected with agriculture (through forward and backward linkages). The Government-economy nexus is depicted in the bottom right hand-side of Figure 1. In the longer-term, it is expected that irrigated agriculture will adjust to water reform through investment in water-saving technologies and other cost-saving technical changes, and through organisational/managerial efficiencies. Nonetheless, as in case of any reform, some sectors may gain and some sectors may be adversely affected. Government's economic policies and regulations create market incentives through price signals targeted at modifying the producers' (irrigators') behaviour, and these modified behaviours may support conservation programs. In terms of water policy reform in the MDB, less and more efficient use of irrigation water by industries will translate into an increase in the flow of water for the environment, thus supporting Government's conservation efforts. This interaction between the economy and the ecosystem is illustrated by the arrow from the economic system to the ecosystem in the right hand-side of Figure 1.

A healthy river system in the MDB is also important to the future irrigation needs of the region and the sustainability of the Basin economy and the Basin community. A sustainable economy supports the livelihood and wellbeing of the community largely through employment and income generation opportunities and the supply of goods and services. The community or the individuals/households, on the other hand, interact with the economic system largely via the supply of labour and expenditure on goods and services. The economy-community/social nexus is depicted at the bottom part of Figure 1. The community, in addition to deriving benefits from the ecosystem, also contributes to the conservation efforts through pressure/interest groups who influence environmental policies. People modify their behaviour in response to regulations (such as imposing fines on dumping rubbish) and incentives (such as recycling). As citizens get more informed about the extent to which the wellbeing of communities depends on a healthy ecosystem either directly and/or indirectly through the economic system, it is likely that they would modify their behaviours that support conservation efforts. This interaction between the community/households and the ecosystem via conservation efforts (which includes community participation and localism, and good governance practices) is depicted on the right hand-side of Figure 1. Tapping local knowledge in designing conservation programs will prove critical in successful conservation outcomes.

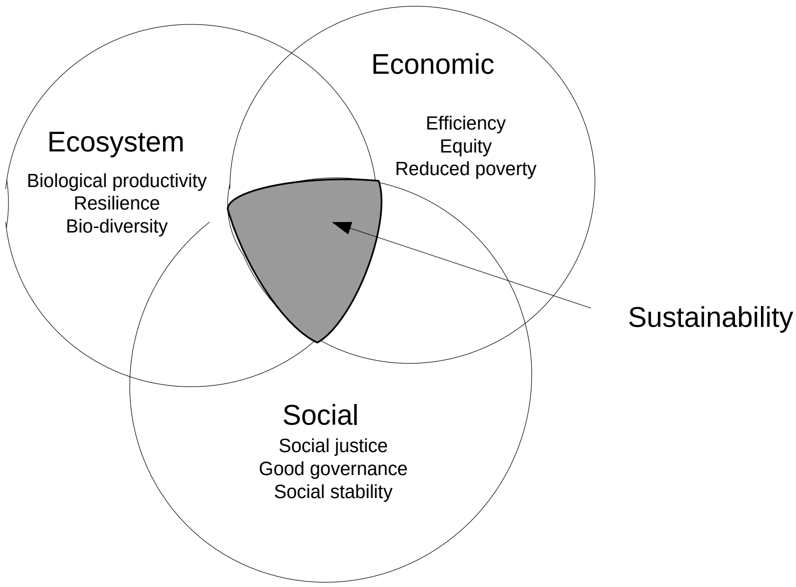


Figure 2: Venn Diagram of Sustainability (Source: Barbier, p.104, 1987; Barbier and Markandya, p.39, 2013).

Ecosystems are increasingly being recognised and treated as an environmental or natural asset or capital, which, as discussed above, provide vital services for the sustainability of the economic and social systems. Like physical capital, ecosystems deplete (depreciate) with use. But unlike physical capital, ecosystems are harder to replace (and some cases impossible to replace once depleted) and maintain. The public goods nature of ecosystems and the associated market failures in the provision of ecosystem services offers additional challenges for achieving optimal balance among the three main systems: the ecological, the economic and the social. Conceptually, the optimal balance in terms of sustainable development[4] is attainable where the goals of the three systems intersect (Barbier, 1987; Barbier and Markandya, 2013) as depicted in Figure 2.

As Figure 2 shows, each of the systems has the desired or "human ascribed" goals (Barbier, 1987). Barbier points out that maximising all the goals may not be possible all the time. For example, increasing economic productivity that is achievable in an efficient and equitable way

[4] The most widely used definition of sustainable development is from the World Commission on Environment and Development (WCED, 1987) commissioned report referred to as the "Brundtland Commission" (after its chairman). It defined sustainable development as: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Barbier and Markandya, 2013).

may still impose some costs on the environment in terms of resource depletion and environmental degradation (thereby adversely affecting bio-diversity and resilience of the ecological system). On the other hand, maximising the goals of biological productivity and diversity has the potential to impose costs on the economic and social systems in terms of reduced economic growth and increase in unemployment and associated social problems (e.g. increase in crime rates, school dropouts, housing and financial stress).

It is difficult to envisage economic growth without imposing any costs to the ecosystem. In this situation, sustainable economic and ecological systems would imply an ecological-economic trade off. However, maximising the goals of one system without accounting for costs it may impose on other systems will produce less than socially optimal outcomes. Thus, in recognising the interdependence of all the three systems, sustainable development would involve maximising the "goals across all these three systems through an adaptive process of trade-offs...." (Barbier, p. 104, 1987). The process of adaptive trade-offs implies that for the systems to exist and thrive in a changing environment, they must have the capacity and capabilities to adapt and evolve. In other words, "agents within adaptive systems interact, react, learn, and co-evolve with their environment" (Buchholz, et al., p. 6088, 2007). The feedback loops in Figures 1 and 2 reflect this adaptive or evolving process. Conceptually, the socially optimal outcome of sustainability is attained at the intersection of the three systems as illustrated by the shaded area in Figure 2.

The water reform policy under the Basin Plan is largely about the trade-offs between the ecosystem and the economy and the social systems, and the impact these trade-offs have on the socio-economic outcomes. Thus, this interdependence of and the need to maximise goals across the three systems has influenced the approach outlined in this paper to modelling the MDB as a complete system, bringing together a number of models to analyse the water policy reform, as described below.

4 A MODEL OF THE MDB SYSTEM

Figure 3 shows in more detail how a number of integrated models might be able to model the interactions (trade-offs) and interdependence between the systems which define the analytical boundaries of a region such as the Murray-Darling Basin. As both Figures 1 and 2 show, the systems are intricately connected directly and indirectly via feedback loops. A perturbation in one system may trigger changes in other systems directly and indirectly. The challenge is to identify these linkages and feedback loops in terms of the variables that connect the systems so that they form internally consistent components of the whole system. That is, the aim is to operationalize the conceptual systems framework discussed in section 3 by identifying and developing a series of models that link the three systems. The links between the models is shown in Figure 3, followed by a more detailed discussion in later sections of this paper.

The MDBA has invested a considerable amount of time analysing the socio-economic impact of water policy reform under a number of Basin Plan modelling scenarios. In coming up with various modelling scenarios, the MDBA has consulted widely with the stakeholders at the business and community levels, including various levels of government and the scientific community (see for instance MDBA, 2012a; 2012b and MDBA, 2012c). The key purpose of this extensive consultation and modelling work is to get the ‘right amount’ of trade-off, which in

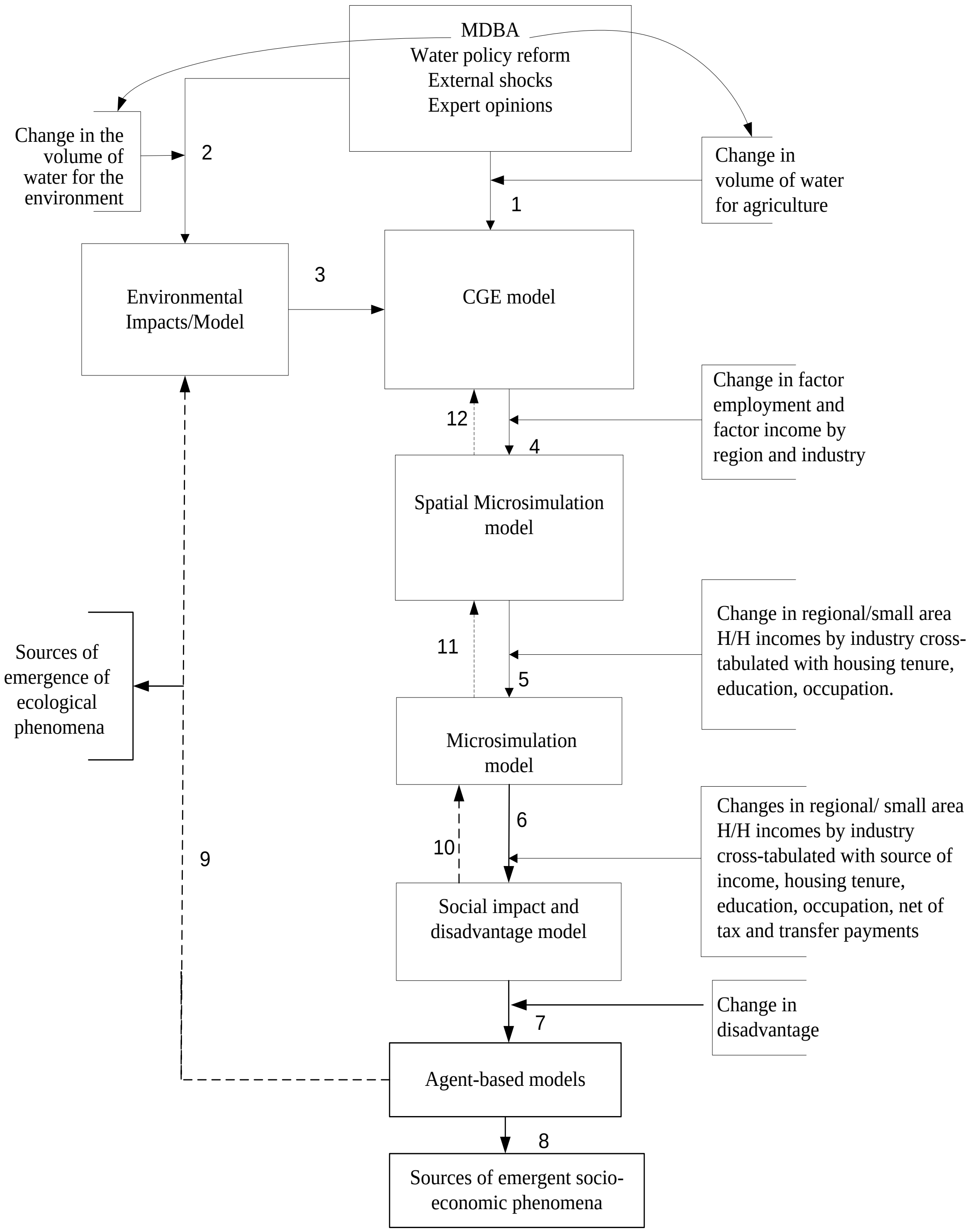


Figure 3: Details of the Interfaces between the environment/ecology and the socio-economic models

the long run can restore the health of the river system and at the same time have minimal adverse socio-economic impacts.

In terms of Figure 2, the MDBA is attempting to maximise goals across the three systems, so that the trade-off falls in the shaded area. Looking at Figure 3, the water policy reform enters the economy via link 1. As mentioned in the Introduction, the water policy reform will largely include the water buyback scheme and water-saving infrastructure investments, both of which translate into reduced amounts of water available for irrigation (link 1) and increased water flows to the environment (link 2).

The economy-wide and the regional impacts (including the MDB) of the water policy reform, that is, the change in the volume of water for irrigated agriculture in the MDB, are captured by a Computable General Equilibrium (CGE) model. How the changes in factor employment and incomes affect the social outcomes across a number of household characteristics/variables are analysed with microsimulation models. First, the CGE model is linked to a spatial microsimulation model to interface with the regional detail of the CGE model (link 4). The spatial microsimulation model could be further modified and extended to include smaller geographical areas than the regions specified in the CGE model, if a smaller area analysis is desired. This brings the change in incomes and employment by industry from the CGE model to the regional/smaller area household level. The output of the spatial microsimulation model is then fed into a national microsimulation model via link 5 to compute the regional/small area level change in household incomes (cross-tabulated by household characteristics/variables) net of federal taxes and transfer payments. The changes in household characteristics are linked to changes in social disadvantage by a social impact model (link 6). Finally, agent-based models can take as inputs the output of a social impact model (such as psychological or financial stress) via link 7 to investigate emergent socio-economic phenomena such as resilient or vulnerable communities. Within the overall model framework shown in Figure 3, the dashed lines show links that are potential linkages for future research that are not incorporated in this paper.

5 ENVIRONMENT/ECOSYSTEM-ECONOMY NEXUS

In the current modelling framework, the environment/ecology and economic systems are exclusively connected via water inputs into the MDB agriculture[5]. As explained above, the quantity of water diverted from the irrigation system (SDLs) to the environmental flows is determined by the MDBA (link 1). Link 3 shows that water flows from the ecological system to the economy. In this regard, the SDLs enter the economic model (the CGE model) as an exogenous policy shock. Thus, as shown in Figure 3, the environment system is exogenous to the economic system given that there is only a one-way link (solid arrow 3) between the environment and the economic systems. In the current modelling framework, there is no

[5] However, it should be noted that commercial activities that rely on the ecosystem services such as tourism activities are connected to the economy as well via link 3 in Figure 3. These ecosystem based tourism activities (and water inputs) are contained in the base period database of the CGE model.

feedback from the socio-economic system to the ecosystem (shown as dashed arrow 9 in Figure 3). In future research, it would be worthwhile to examine the feasibility of linking and integrating the two systems such via agent-based models.

6 Socio-economic nexus: the link between Macro-Economic factors, Structural Change and Income Distributions

As link 1 in Figure 3 shows, the economic impact of the water policy reform is analysed by using a CGE model. CGE models provide a rigorous way to quantitatively measure and evaluate the impact of policy reforms (such as the water policy reform under the Basin Plan) in the economy as a whole. CGE modelling, based on the input-output linkages of the economy, models the structure of the whole economy and therefore the details of all existing interactions among economic agents (producers, consumers, investors, government and the rest of the world, among others). Because of this interconnectedness of markets and agents in a CGE model, the CGE analysis captures a wider range of economic impacts of an external shock or a policy reform, compared to other available techniques (such as the partial equilibrium models). In this regard, CGE models are better equipped to evaluate policy shocks whose impacts are expected to be complex, transmitted by different channels, and materialize not only in one but various rounds through feedback loops via interconnected markets. Moreover, given that the CGE models are designed to evaluate the economy-wide impacts, it not only captures the structural changes in the economy as a whole but also clearly identifies the winners and losers (sectors, regions, occupations, and so forth) of a policy reform or an external shock.

However, the inadequacy of the use of CGE models for distributional analysis is well recognised in the income distribution literature. This is because, traditionally, CGE models include only a limited number of representative households, so do not account for the diversity of individual or household characteristics required for a detailed distributional analysis. In this regard, a companion microsimulation model can be combined with a CGE model to analyse income distributional issues of policy change or an external shock. The strength of the microsimulation models is that they account for individual heterogeneity by making use of nationally representative household surveys of the population. The effects of a macro policy captured by a CGE model can be passed down to a microsimulation model for detailed distributional analysis. The benefit of combining CGE and microsimulation models is that it overcomes the problem of a lack of general equilibrium effects in microsimulation models and the limitations of the restrictive assumption of representative households in the CGE model (Hérault, 2006).

Microsimulation models can be classified into static and dynamic models, which in turn can be subdivided into non-behavioural and behavioural models. The static microsimulation models are largely designed for short-term analysis. Simulations with static microsimulation models assume that the size and the demographic characteristics of the population remain fixed over the simulation period. That is, they remain as they are in the base period after the simulation. On other hand, dynamic microsimulation models capture medium to long-term analysis. In these models, the size and the demographic characteristics of the population change over the simulation period (Hérault, 2010).

Non-behavioural microsimulation models capture the “morning after” effect of a policy change. In other words, the individuals are assumed not to change their optimal choices in response to a policy change, for example, with regard to their supply of labour or consumption patterns – the behaviour remains the same after the policy simulation, as it was pre-policy simulation. Because of this non-behavioural response to policy changes, non-behavioural microsimulation models are also called arithmetic or micro-accounting models. In this regard, these models are seen to capture only the first round welfare effects of policy changes. For this reason, non-behavioural microsimulation models are not suited to simulating large shocks or for medium and long-term analysis, when the behavioural responses of individuals and households cannot be ignored (Ribilliard, et al., 2008).

Behavioural microsimulation models allow individuals to adjust their behaviour in response to a policy change – the optimal choices change and are reflected in the changes in, for example, the labour supply responses and consumption patterns after the policy simulations. Hence, behavioural microsimulation models are designed to simulate large shocks and for medium and long- term analysis.

In the sub-sections below (sub-sections 6.1-6.4), a review of the recent literature is undertaken to discuss four approaches to linking a CGE model to a microsimulation model for distributional analysis of policy reforms and external shocks. The first approach is the integrated approach. The other three approaches involve sequentially linking the CGE model to the microsimulation model in a top down, bottom up and top down-bottom up fashion. Sequentially linking CGE and microsimulation models is also called the layered approach to distributional analysis. A layered approach to macro-micro link is considered less complex than an integrated approach as the former involves only sharing information between two standalone models.

6.1 CGE Models and Income Distribution: The integrated Approach

Most CGE models provide a relatively disaggregated (sectoral, regional, occupations and skill/qualifications) representation of the economy. However, as mentioned above, traditionally, one or only a small number of representative household groups describe the income distribution in most CGE models. By modelling a small number of representative households, the CGE models do not capture the heterogeneity of the households represented in the population and thus have limited application to distributional analysis. This is because the representative household approach to income distribution in CGE models is based on the assumption that the households within the representative household groups are homogenous (no intra-group income changes). In other cases, the intra-group household heterogeneity is recognised by assuming “that the distribution of relative incomes within each representative household follows as exogenous statistical law” (Colombo, p72, 2010). Thus, any distributional analysis of income is limited to comparing average income variations between the representative households. Savard (2003, p 4) notes the shortcomings of this approach to distributive analysis as follows:

> The main drawback of this approach is that it supposes either that there is no intra-group income distribution change, or that this intra-group distribution change is linked to a theoretical statistical relationship between average and variance of the distribution of the lognormal distribution. There is no economic behaviour behind this change in intra-group distribution. We can easily see that the average behaviour of a specific group is biased towards the richest in the group. As they are the ones endowed with most of the factors, their behaviour will be dominant in the group (Savard, 2003, p4).

The point to note is that with a small number of representative households, the existence of heterogeneity in household behaviour within representative households can be as significant as between them. Moreover, empirical studies using household surveys "show that within-group component of observed changes in income distribution is generally as important as the between-group component of these observed changes" (Colombo, 2010, p72).

The solution to this problem, within the CGE framework, is to increase the number of households in the CGE model, with each household representing a homogenous population group in the model. More specifically, this approach involves "explicitly integrating into a CGE model each household from a nationally representative household survey" (Cockburn et al., p60, 2010). This approach requires no modifications to the CGE model: the representative households are simply replaced by "real" households from a nationally representative household survey. The household detail comes from a nationally representative household survey, where each "real" household in the survey data represents a homogenous group in the population by definition. The individual/household survey data contains important observed information on household consumption and income cross-classified by a host of individual/household characteristics such as age, education, gender, housing tenure, occupation, regions, industries and so forth. This degree of detail is desirable to analyse in a meaningful way the distributive impact on the individuals/households of macro and structural changes in an economy. Moreover, the consumer demand theory of the representative households in the model is the same theory applied to each "real" household in the expanded household module. In terms of Figure 3, the CGE and the microsimulation model now become internally consistent parts of a single model – no longer distinguished separately. In other words, the models are not *linked* (as discussed in sub-sections 6.2-6.4 below) but fully *integrated* in a single model, which is solved simultaneously (rather than sequentially or iteratively).

In this integrated approach, as the household income and expenditure data in the model's database and the national household survey come from different sources and are likely to be from different years, these two datasets need to be adjusted and reconciled to complete the integration process. Cockburn et al. (2010) describe in detail how they adjusted and reconciled the SAM and household surveys data for Nepal and the Philippines to illustrate the workings of the integrated model. For Nepal, the authors integrated 3,388 households and for the Philippines 24,797 households into the respective countries CGE models – the household data coming from nationally representative household surveys. In reconciling the SAM data and household survey data for each country, the authors noted the following:

> There is no magic recipe for reconciliation. A thorough understanding of both datasets is required and reasonable assumptions have to be made with the ultimate aim of creating a better and coherent dataset with least possible adjustment (Cockburn et al., 2010, p62).

A review of the different methods and procedures to reconcile datasets is out of the scope of this paper but would be a useful exercise when considering integrating "real" household data in a CGE model to analyse the income distributive impact macro and structural changes. A thorough review of different methods may provide important insights into further refinements of existing methodology and development of new approaches - all aimed at reconciling data efficiently.

6.2 SEQUENTIALLY LINKING A CGE MODEL TO A MICROSIMULATION MODEL: THE TOP DOWN APPROACH

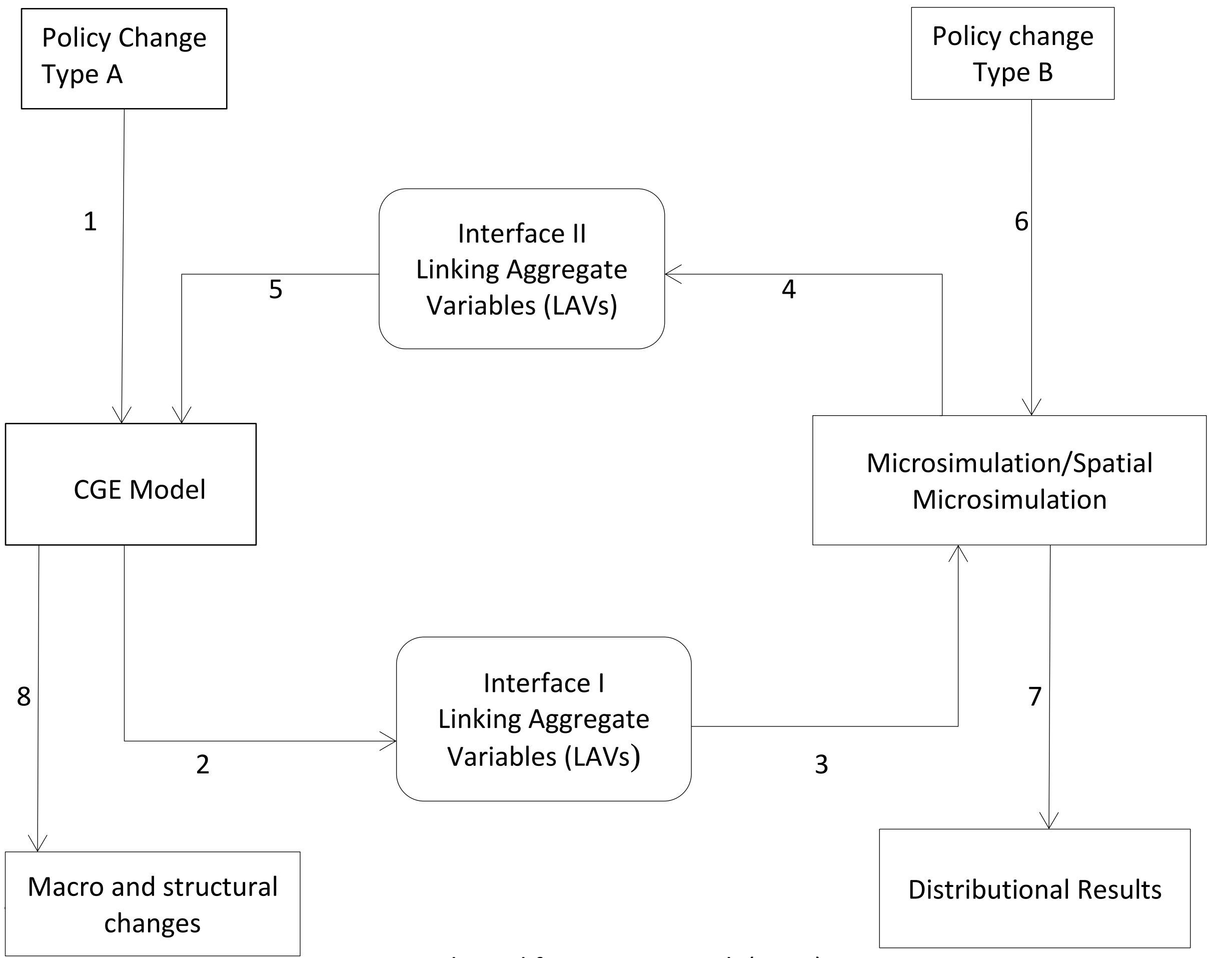
Sequentially linking a CGE model to a microsimulation model is explained with reference to Figure 4. A top-down approach proceeds in a two-step fashion. First, a CGE simulation of the impact of macro-level changes, induced by policy change or external shock type A (link 1 in Figure 4), is solved. Second, its solution in terms of the selected variables of interest (such as a vector of aggregate prices, wages and employment variables), called linking aggregate variables (LAVs) are fed into the microsimulation model via Interface 1 (links 2 and 3) in Figure 4. The microsimulation model then uses the change in the (LAVs) produced by the CGE model to capture the changes in the distribution of income, as shown by link 7 in Figure 4[6]. In a behavioural microsimulation approach, the consistency with CGE results is largely achieved by adjusting the parameters of the behavioural microsimulation model. In the non-behavioural microsimulation approach, the consistency between the two models is achieved largely by using a reweighting procedure, that is, by altering the sample weights, to reproduce the CGE results as captured by the linking aggregate variables. Some of the recent non-Australian studies using a top down approach are discussed briefly below.

Bourguignon, et al. (2003) linked a CGE model to a behavioural microsimulation model (a household income generating model) in a top down fashion to analyse the distributional impact of a terms of trade shock (resulting in devaluation) to the Indonesian economy. In this approach, the microsimulation model generates changes in variables (such as wages/incomes and employment - the linking aggregate variables) that are consistent with the results generated by the CGE model. The authors also used the same CGE- microsimulation models and the top down approach to analyse the impact of 1997 financial crisis on poverty and inequality over a historical period in Indonesia (Ribilliard, 2008). A similar approach is used by Lay (2010) to simulate the effects of a multilateral trade liberalisation and a gas boom on income distribution in Brazil and Bolivia respectively.

[6] Note only links 1, 2, 3 and 7 are relevant in the top down approach in Figure 4 - other links are ignored.

Hérault (2010) uses a top down approach to link a CGE model with both a behavioural and a non-behavioural microsimulation model to analyse the income distributional impacts of trade liberalisation in South Africa. The CGE-behavioural microsimulation approach used here is similar to that of Bourguignon, et al. (2003), where a microsimulation model generates changes that are consistent with the output (linking aggregate variables) of the CGE model. On the other hand, the CGE-non-behavioural microsimulation approach uses a reweighting procedure to reproduce the changes in the linking aggregate variables (consumer prices, returns from capital and labour, and employment levels) passed down by the CGE model (also see Hérault, 2006; 2007). Following the approach developed by Savard (2003) and Robilliard et al. (2008), Raihan (2010) linked a dynamic CGE model to a behavioural microsimulation model in a top down fashion to analyse the welfare and poverty effects of trade liberation in Bangladesh.

Figure 4: A stylised representation of CGE-Microsimulation linkages



Source: Adapted from Dixon, et al. (1996)

6.3 SEQUENTIALLY LINKING A MICRO-SIMULATION MODEL TO A CGE MODEL: THE BOTTOM UP APPROACH

There may be cases when government policy changes or reforms may directly affect individuals and/or households, such as changes in the tax and benefit system. It may be of interest to know the economy-wide impacts of the changes in the distribution of income, labour supply and consumption patterns of households, as a result of a change in the tax and/or benefits system. In terms of Figure 4, the policy change (such as a change in the tax and benefits) enters the microsimulation model via link 6. The output of the microsimulation model (the linking aggregate variables) then enters the CGE model via Interface II (links 4 and 5) in a bottom up fashion. The CGE model adjusts to the linking aggregate variables produced by the microsimulation model to capture the macro and structural changes in the economy, shown by link 8 in Figure 4[7].

6.4 SEQUENTIALLY LINKING A MICRO-SIMULATION MODEL TO A CGE MODEL: THE TOP DOWN-BOTTOM UP APPROACH

A top down-bottom up approach attempts to introduce a bi-directional link between the two models. The two models influence each other at various stages through feedback loops. The feedback loops are used to run both models iteratively until the two produce convergent results. If the perturbation of the system begins from the macro/CGE side (link 1 in Figure 4), then the output of the CGE model enters the microsimulation model via Interface I and in turn, the output of the microsimulation model is fed back (exogenously) into the CGE model via Interface II. This iterative process (sequentially feeding the output of one model into another) continues until both models produce convergent outputs. The final solution to the microsimulation model produces the changes in the distribution of income, shown by link 7 in Figure 4. Similarly, if the policy change originates from the microsimulation (micro) side of the system (link 6), then the output of the microsimulation model enters the CGE model via Interface II and in turn, the output of the CGE model enters the microsimulation model via Interface I. This iterative process continues until both models produce convergent outputs. The final solution to the CGE model produces the macro and structural changes in the economy, shown by link 8 in Figure 4.

Bourguignon and Savard (2008) linked a CGE model to a behavioural microsimulation model in a both top down and top down-bottom up fashion to analyse the distributional impacts of trade liberalisation policies in the Philippines. In comparing the two approaches, the authors found the differences in the approaches were important in the presence of imperfections (i.e. wage rigidities) in the labour market. It is worth noting that in the three layered approaches discussed above, some degree of data reconciliation is also required between the two models but significantly less than required in the fully integrated approach discussed in section 6.1.

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[7] Note only links 4, 5, 6 and 8 are relevant in the bottom up approach in Figure 4 - other links are ignored.

6.5 CGE-MICROSIMULATION LINKAGES: THE AUSTRALIAN EXPERIENCE

There are some studies within Australia that attempt to link a CGE model with a microsimulation model to analyse the distributional impacts of policy changes. A study by Meagher and Agrawal (1986), considered the first CGE-microsimulation income distribution analysis in Australia, used a top-down approach to analyse the impacts of the 1985 proposed taxation reform (Australian Government, 1985) on the distribution of personal incomes. First, a CGE model, ORANI-NAGA (Dixon et al., 1985) was used to capture the effects of the tax reform on factor incomes and employment. Second, the unit records of the 1981-82 Survey of Income and Housing Costs (SIHC) were reweighted to target the output of the CGE model (i.e. changes in factor incomes and employment), which were the linking aggregate variables between the two models. The microsimulation model was non-behavioural and falls in the arithmetic or micro-accounting class of microsimulation models.

A decade later, Meagher (1996) extended the static CGE-microsimulation analysis of Meagher and Agrawal (1986) by replacing the static ORANI-NAGA CGE model with a dynamic CGE model – the MONASH model of the Australian economy (Adams, et al., 1994) to generate a baseline (business as usual) forecast of the changes in the distribution of incomes over the period 1990-91 to 1996-97. Dixon et al. (1996) extended the CGE-microsimulation top down approach of Meagher and Agrawal (1986) to analyse the distributional impacts of microeconomic reform over the period 1994-95 to 2003-04. First, the microeconomic reform, modelled as positive sectoral shocks, enters the CGE model to capture the structural changes in the economy. Second, the average annual changes of the relevant variables of interest in the MONASH model over the period 1994-95 to 2003-04 were passed on to a non-behavioural microsimulation module (i.e. applied to the income data for 1989-90 from the Survey of Income and Housing Costs) to analyse the distributional impacts of the microeconomic reforms. Polette and Robinson (1997) used a static version of the MONASH CGE model and STINMOD[8], a static microsimulation model, in a top down approach to analyse the distributional impacts of a uniform economy-wide labour-saving technology or productivity shock. The output of the CGE model (changes in employment by occupation and State) were then used to re-weight the microsimulation model to analyse the distributional impacts.

Brown, et al. (2007) used a bottom up CGE-microsimulation approach to assess how the health outcomes of a hypothetical diabetes prevention program affect the broader Australian economy. The microsimulation component had two models linked as follows. A 'Diabetes Model' developed by NATSEM, was used to estimate the number of cases of type 2 diabetes in Australia that can be prevented through a diabetes prevention program, including any likely savings in direct health care costs as a result of the program. This information was then fed into a conventional household labour supply model, developed by the Centre for Health Economics at Monash University, to identify the impact of diabetes on employment and the diabetes prevention program on the labour supply. This information in turn was passed on to

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[8] STINMOD is a static microsimulation model, developed at National Centre for Social and Economic Modelling (NATSEM), University of Canberra, to analyse the distributive impacts of tax and transfers on incomes of Australian families, including the impact such policies may have on the federal budget (Lambert, et al., 1994).

the MONASH model, the dynamic CGE model (Dixon and Rimmer, 2002) to estimate the economy-wide effects of the program.

Buddelmeyer, et al. (2009) used a top down approach to link a dynamic CGE model, the Monash Multi-Regional Forecasting (MMRF) – Green model (Adams, et al., 2002, 2007), to a microsimulation model, the Melbourne Institute Tax and Transfer Simulator (MITTS) (Creedy et al., 2002), to predict the effects of climate-change mitigation policies on income distribution in Australia from 2005 to 2030. Similar to typical top down approaches, the output of the CGE model (such as wages and employment by industry and region) was reproduced using a reweighting procedure in MITTS to compute the changes in the net household incomes of a representative sample of households. The study used a non-behavioural version of MITTS to link to the CGE model.

Verikios and Zang (2010) used a top down approach to analyse the distributive impact of microeconomic reform[9] of the Gas industry during the 1990s. The authors used a bottom up multi-region CGE model, the Monash Multi-Region Forecasting (MMRF) model (Naqvi and Peter, 1996) to generate region-specific changes in commodity prices, factor prices and factor employment resulting from the Gas industry reforms. This information was then passed down to a microsimulation model to analyse the distributive impacts of the reforms on the regions and households. A similar study by the authors (Verikios and Zang, 2012), analysed the distributional impacts of the Hilmer reforms of Australian ports and rail freight industries.

7 The distributional impacts of the Basin Plan: A CGE-microsimulation analytical framework

As the above literature review demonstrates, the CGE-microsimulation link overcomes the lack of general equilibrium effects in a microsimulation model on the one-hand and the restrictive representative household assumptions of CGE models on the other. It is also clear that drawing on the strengths of both models allows a richer understanding of the micro impacts of (macro) policy reforms. The irrigation and environmental water policy reform under the Commonwealth's Basin Plan will affect the economy and the community in different ways as a result of structural changes in the economy. In the long-term, some individuals and households may come out winners and some as losers. In this regard, the micro (distributional) impacts of policy reforms help identify the winners, losers and the vulnerable in the communities. It therefore provides policy makers an informed basis on which to arrive at measures to help the economy and the community to adjust, including what the measures are likely to cost.

Given that it would be the first attempt to analyse the distributional impacts of water policy reform in the MDB using a CGE-microsimulation modelling framework, it would be prudent to start with a relatively less complex top down approach to linking the CGE and microsimulation

[9] The microeconomic reforms relating to the infrastructure industries were part of the reforms of the Hilmer Report on National Competition Policy (Commonwealth of Australia, 1993), which subsequently led to creation of the National Competition Reform Act 1995 and other associated agreement (s) between the Australian federal and state/territory jurisdictions to facilitate the implementation of the reforms.

models than more complex approaches. That is, the development of the CGE-microsimulation framework for distributional analysis can proceed from a top down to top down-bottom up, followed by a fully integrated approach. Accordingly, the rest of this paper discusses the top down approach to linking a CGE and microsimulation model to analyse the distributional impacts of water policy reform under the MDB plan.

As is evident from the preceding discussions, capturing the macro and structural (sectoral, employment and regional) changes of water policy reform require a macro-modelling framework such as CGE modelling. The desired features of such a CGE model are discussed in the section below (section 7.1). To capture the micro or heterogeneous effects on individuals and households of the structural changes driven by the water reform policies require a microeconomic perspective that can be conducted using microsimulation models. Three microsimulation models are used. First, the CGE model is linked to a spatial microsimulation model to interface with the regional detail of the MDB contained the CGE model. The features of such a spatial microsimulation model are discussed in section 7.2. Second, in section 7.3, the top down link between a CGE and a spatial microsimulation model is discussed, followed by a discussion in section 7.4 of the link between the spatial microsimulation model and a national microsimulation model to get income at the household level net of tax and transfer payments. The link between the microsimulation model and a social impact and disadvantage model is then discussed. Finally, in section 7.6, a potential link between the community (microsimulation) and ecology via a feedback loop (link 9 in Figure 3) using agent-based models is briefly discussed. This section also briefly discusses how the output of a social impact model (such as psychological stress) can be used by agent-based models to uncover the key factors or variables that underlie resilient or vulnerable communities.

7.1 The desirable features of a CGE model to analyse water reform policies in a regional economy such as the MDB

For analytical purposes, the MDB, which is spread over four states and one territory, is treated as a single regional economy. However, up to 40 sub-regions within the Basin are distinguished in studies of the Basin Plan capturing the irrigated (and non-irrigated) agricultural detail and water markets in each of the sub-regions of the Basin[10]. Note the key component of the Basin Plan is the water buyback scheme, under which irrigation water is gradually diverted to environmental flows via a permanent purchase of water rights from the farmers in the Basin. That is, the farmers are faced with the reality of reduced water inputs for irrigation. Farm activities, being commercial entities, are likely to respond to the reduced supply of a factor of production, and the consequent increase in its price. Economic models can capture such producer behaviour (that is, changes in producers' production decisions) in response to a policy such as the implementation of SDLs in the Basin economy. However, changes in the production decisions of the farmers have flow-on effects on the regions of the Basin, on the Basin itself and on the rest of the economy. In this regard, an economy-wide computable

[10] For instance, the TERM-H20's (a 'bottom up' multi-regional multi-sectoral model of the Australian economy) database distinguishes 40 sub-regions in the MDB at the statistical subdivision level (Dixon, et al., 2012).

general equilibrium (CGE) model would be an appropriate model to capture the flow-on economic impacts in a single analytical framework.

Note that the water policy reform under the Basin Plan directly affects the MDB region – it does not *directly* affect the rest of Australia. In this regard, the implementation of the SDLs is a regional-specific policy shock, originating from the MDB. From the socio-economic impact perceptive, policy makers are interested in:

1) How the policy affects the agricultural industries in the Basin, including the changes in the production/crop mix, the use of factors of production such as land and water, consumption, employment and so forth;

2) the impact that this regional-specific shock may have on the rest of the Australian economy, including the impact of any feedback from changes in the rest of the economy back to the Basin regional economy; and

3) the welfare implications of the policy on households in the Basin and the rest of the economy.

Thus, it is desirable that a CGE model for estimating the economic impact of the Basin Plan have the following key features[11]:

1) It contains the required regional and sectoral detail, in particular small region (area) representation. The small region detail in a single country CGE model allows the modeller to comprehensively analyse local issues by treating a small regional economy as a separate economy with complete input-output linkages and behavioural theory of a typical national CGE model. Treating (small) regions as separate economies make it possible to examine the regional and national impacts of shocks that are region-specific. Small area representation is also desirable because it captures the decentralised decision-making in small regions and communities, allowing price signals to determine the allocation of resources within an economy-wide analytical framework such as CGE modelling. The recognition of each regional economy (such as the MDB) as a separate economy is the first building block of the "bottom up" approach to CGE modelling.

2) Whether the model is dynamic. Dynamic models capture both the short-run and the long-run effects of the model simulations. In addition, with regards to the Basin Plan, the dynamic nature of a CGE model allows the modeller to take into account in the baseline forecasts the variability of water availability over the simulation period. They are also useful for policy simulations. For instance, the model can take into account a

[11] The two CGE models used in MDBA commissioned studies on the macro, regional and sectoral impacts of the SDLs are the TERM-H20 (Glyn, 2011) and ABARES' AusRegion and Water Trade Model (ABARES, 2011). TERM-H20 incorporates all the 5 features listed below. AusRegion, the regional CGE model contains all the CGE features but has a separate water trade model to handle water markets that is exogenously linked to AusRegion.

policy implementation (such as a SDL scenario) which is spread over several years or seasons.

3) Whether the models sectorial and regional details, including the water markets, are all incorporated in a single analytical framework. Having one integrated model with interaction between different systems (economic and water) is preferable to having two separate models joined by the output of one feeding into the input of another.

4) The model needs to incorporate inputs and factors of production that are relevant to the MDB. This will allow relevant and realistic scenarios to be derived, and will add to the flexibility of the model.

5) The model must also be designed to handle the impacts of revenues and expenditures that flow into the economy through the water buyback scheme and water-saving infrastructure investment respectively.

7.2 SPATIAL MICROSIMULATION MODEL FOR DISTRIBUTIONAL IMPACTS OF WATER REFORM IN THE MDB.

Spatial microsimulation is a technique to derive datasets of small areas not normally captured by the official sample surveys. In case of Australia, the official sample surveys from Australian Bureau of Statistics (ABS) are "designed to provide estimates for Australian states and territories, but not many areas that are smaller than these" (Tanton, et al., p.1, 2011). As noted earlier, the MDB region covers areas across four states and one territory. The regions in the MDB are thus a collection of statistical areas identified in the ABS census data, such as Local Government Areas (LGAs) or Statistical Area 1 (SA1). These local or regional areas are not captured in ABS's official sample surveys (such as the Survey of Income and Housing (SIH), and Household Expenditure Survey (HES)). Thus, in order to conduct a meaningful distributional impact of water reforms in the MDB communities, a dataset for the Basin, which is appropriate for the distributional analysis, needs to be derived using a spatial microsimulation procedure.

To derive a spatial dataset for the MDB for distributional analysis, a spatial microsimulation model (SpatialMSM)[12], developed at the National Centre for Social and Economic Modelling (NATSEM), University of Canberra can be used. This spatial microsimulation model uses a reweighting procedure to generate small area datasets using the following method. First, from the census data of a small area such as an SA1, the individual or household characteristics/variables of interest (such as income, age and education) are identified and extracted from ABS Census TableBuilder. These are the constraint tables and are treated as the Census benchmark data for the small area. Second, the same characteristics/variables of the individuals or households are identified and selected from official surveys such as the SIH or the HES. These variables of interest must be defined in the same way on both the Census and the official sample surveys. Finally, the spatial microsimulation uses a reweighting procedure

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[12] The spatial microsimulation (SpatialMSM) was developed at NATSEM, University of Canberra starting in 2003, as part of its continuing efforts to develop small area microsimulation models (Chin and Harding, 2007).

to target the benchmark data from the census, thus creating a synthetic household dataset for a small area. This dataset can then be used to generate household characteristics of interest to analyse the distributional impacts of a policy change in a small area. A description of the steps to derive a small area database using spatial microsimulation is described in Chin and Harding (2007) and Cassells et al. (2013). A more technical description of the spatial methodology is given in Chin and Harding (2006) and Chin et al., (2006). The reweighting algorithm underlying the spatial microsimulation methodology is outlined in Tanton et al. (2011).

There are a number of Australian studies which have used the spatial microsimulation methodology to analyse spatial effects. For example, Tanton, et al. (2009) analysed the spatial impact of an increase in single age pension on the distribution of poverty among older single people. Chin et al. (2005) analysed the spatial effects of tax cuts in the 2004-05 Australian Government Budget. Tanton (2011) compared different poverty rates for small areas and Chin et al. (2005) analysed income, tax and social security benefits for Statistical Local Areas (SLAs) in Australia.

7.3 A TOP DOWN CGE-MICROSIMULATION LINK TO ANALYSE WATER REFORMS OR EXTERNAL SHOCKS

As a starting point to analyse the distributional impacts of water policy reform in the MDB, a top down approach to CGE-microsimulation can be used. In terms of Figure 4, the water policy shock enters to the CGE model via link 1. The results from the CGE model would capture the macro and structural/sectoral changes in the Australian economy and the regional economy of the MDB. Given the regional nature of the water policy shock, the immediate impact of the shock would be on the regional economy of the MDB and thus, the distributional impact of the structural changes in the MDB economy would directly affect the individuals and households in the specific MDB region. As pointed out in section 7.1, the appropriate CGE model to analyse the water policy reform must capture the regional details of the MDB. This means the impact coefficient of the water policy shock could vary by region. In such a case, it would be necessary to pass the different regional impacts of the CGE output into the microsimulation model.

In this regard, in constructing a spatial dataset of the MDB the following are relevant. First, a spatial dataset of the MDB must contain regions that exactly match the regions of the MDB contained in the CGE database - the regions becoming the primary linking aggregate variables between the CGE and the spatial microsimulation model. Second, if even smaller regions in the MDB are desired for distributional analysis, the spatial dataset could be extended to contain smaller area detail. The linking aggregate variables shown in Interface I in Figure 4, which would be relevant for distributional analysis in a top down approach, are the changes in the factor incomes by industry (largely rental and wages), employment by industry and occupation, and changes in consumer prices. These variables enter SpatialMSM via link 4. SpatialMSM then estimates the impact of changes in the factor incomes and employment by industry and occupation on household income in different family or household type, housing tenure, education level and other characteristics of the employee and income earner in the MDB regions and/or smaller areas within the MDB regions.

7.4 A TOP DOWN SPATIALMSM-STINMOD LINK

The changes of income and employment status are likely to affect a household's tax payment to the government and transfer payment from the government according to their family characteristics. In order to calculate the changes in the Commonwealth's tax and transfer payments, the output (the linking aggregate variables) would be fed in STINMOD, a static (and non-behavioural) federal tax and transfer payments model of the Australian economy. STINMOD estimates the changes in household income of federal tax and transfer payments for each different family observed in the microdata in the regions and/or smaller areas of interest in the MDB. These results allow the estimation of a number of social indicators arising from the changes in income distribution such as poverty rates (Tanton, et al., 2009) and housing stress (Nepal, et al., 2010). This method could also be used to measure the dependency on federal government transfer programs and what these programs are likely to cost. The social indicators after the impact of the tax and transfer system gives a comparison between the socio-economic status of individuals and households in the base case (or business as usual) scenario and after water policy reform scenario.

7.5 A TOP DOWN STINMOD-SOCIAL IMPACT AND DISADVANTAGE MODEL (SIDMOD) LINK

It may be desirable to know the impact that the water policy reforms have on the social disadvantage of the communities in the Basin, especially wellbeing indicators such as financial stress, subjective wellbeing and mental health. So far microsimulation has been used to calculate indicators based on direct calculations using the synthetic observations in the microsimulation model, like income and housing costs. The next step towards establishing social impacts is to build a model that takes inputs from the microsimulation model to compute indicators of social disadvantage that are not available in the current microdata. The subjective well-being of communities in the MDB is one example of an indicator that could be affected by water policy reform and that is not currently available on the microdata. To estimate such a variable, the model needs to be built from a database that contains the variables of interest. The Household, Income and Labour Dynamics in Australia (HILDA) Survey[13] is an example of a database that can be the starting point to build such a model.

7.6 MICROSIMULATION/SOCIAL-ECOLOGY NEXUS

To complete the links and the feedback loops between the systems/models in the overall analytical framework, it may be desirable to link the microsimulation models (via link 9 in Figure 3) to the ecological system. An agent-based model seems to be an appropriate model for the feedback loop from the social system back to the ecological system - in particular - how

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[13] The Household, Income and Labour Dynamics in Australia (HILDA) Survey is an Australian household-based panel study, which began in 2001. It collects information about economic and subjective well-being, labour market dynamics and family dynamics. The responsibility for the design and management of the survey rests with the Melbourne Institute of Applied Economic and Social Research, University of Melbourne (see http://www.melbourneinstitute.com/hilda/).

individual human decisions and interactions among themselves and with the ecology simulate observed emergent macroscale socio-ecological outcomes.

Moreover, the microsimulation models used in the framework are static and non-behavioural. Dynamics and behavioural responses can be introduced in the framework via agent-based models to understand emergent socio-economic phenomena such the emergence of resilient or vulnerable communities that are exposed to prolonged climatic events such as droughts. The goal will be to identify and analyse the drivers or sources of emergence of resilient or vulnerable communities in the MDB to inform policy. Agent-based models can potentially take as inputs the output of SIDMOD (such as measures of psychological stress and subjective well-being) to investigate whether these factors (among others) explain emergence of resilient or vulnerable communities.

8 SUMMARY AND CONCLUSION

Systems or integrated approaches to modelling the ecological, economic and social systems to analyse socio-economic and environmental policies are well established in the sustainable development literature. With this in mind, this paper set out to achieve three broad objectives, discussed in three parts of the paper respectively, with regards to water policy reform in the MDB. The first part of the paper outlined a conceptual framework that captures the main interdependencies and interactions among the ecological, economic and social systems of the MDB, thus recognising that a disturbance (through either a policy or an external shock) in one system will trigger changes in all the systems directly and indirectly through feedback loops. In this regard, the paper briefly discussed the main linkages among the three systems in the context of the MDB. It was noted that sustainability implies making (policy) trade-offs, and conceptually, sustainability is attained when trade-offs are achieved in a way that optimises the goals across all the three systems.

The second part of the paper focussed on making the conceptual framework operational, that is, to develop an analytical framework that captures the interdependencies and interactions of the systems in the MDB by identifying the variables and a number of models that connect the systems directly and via feedback loops. The models are the analytical tools suitable to analyse comprehensively the impacts of the water policy reform. The water policy reform under the Basin Plan has two main components: the buyback of permanent water rights from farmers to increase the environmental flows and investments in water-saving infrastructure to assist the farmers to adjust to the new water policy regime. The outcomes of the water policy reform are reduced inputs of water for irrigated agriculture in the MDB and an increased flow of water to the environment. Determining the 'right amount' for the SDLs (Sustainable Diversion Limits) has been one of the major challenges facing the MDBA – that is, what should the size of the SDLs be, which in the long-run restores the health of the river system with minimal costs (if any) to the economic and social systems. In other words, what is the optimal trade-off, in terms of water availability, between the goals of the ecology and the economy? This is the ecology-economy nexus – the two systems connected by water flows[14].

In terms of the system documented in this paper, the water policy shock enters the economy via the CGE model. The CGE model estimates the macro and structural (such as sectoral, regional and occupational) changes of the shock. The CGE model, by modelling the optimising behaviour of economic agents via interconnected markets, captures the complete transmission of the shock, thus clearly identifying the winners and losers in terms of sectors, regions/sub-regions and occupations in the Basin itself and rest of the economy. However, CGE models, by traditionally modelling a small number of representative households, have proved to be inadequate for distributional analysis. To capture the individual and household heterogeneity needed for distributional analyses, this paper discussed two main approaches found in recent literature: the integrated and layered approaches to modelling individual/heterogeneity.

In the integrated approach, the representative households in a CGE model are simply replaced by the "real" households from a nationally representative survey. In the layered approach, a CGE model can be sequentially linked to a microsimulation model that is designed to capture individual/household heterogeneity (from a nationally representative survey), in a top down, bottom up, and top down-bottom up fashion. The integrated approach is perhaps the ideal approach given that the household or microsimulation module is fully integrated with the CGE model. However, in this approach, a full reconciliation of household data between the CGE database (derived from input-output tables) and the expanded household module dataset (derived from a nationally representative survey) is needed, which can be very demanding. In the layered approaches, some data reconciliation between the two-standalone models is required, but not to the extent required for the integrated approach.

Given that this is a first attempt to analyse the distributional impacts of water policy reform using the CGE-microsimulation modelling framework, it is prudent to proceed from a relatively less complex top down approach to link a CGE model with a microsimulation model. The obvious shortcoming of this approach is that there no feedback from the microsimulation model to the CGE model. Thus, in the next step in the model development it would be desirable to link the microsimulation model bottom up to the CGE model, thereby having a bi-directional link between the models (depicted by dashed arrows 10, 11 and 12 in Figure 3). This could be followed by fully integrating the microsimulation model into the CGE model. It would be useful to compare the results of the three approaches, all under one policy scenario, that of water policy reform in the MDB.

In this regard, the paper has outlined the top down approach to CGE-microsimulation linkage as the starting point to analyse the macro, structural and distributional impacts of the water

[14] It is worth noting that the subsequent health of the river system in the MDB as the result of increased environmental flows and its implications for the future supply of water for irrigation is outside the current analytical framework.

policy reform. It was noted that a CGE model (such as TERM-H20[15]), which captures the regional and sectoral detail, and the water markets in MDB, as the appropriate CGE model for this analytical framework. In addition, the three sequentially linked models (SpatialMSM, STINMOD and SIDMOD) in a top-down fashion are the relevant models for distributional analysis. Given the regional nature of the water policy shock, the output from the CGE model (variables capturing the structural changes such factor employment and returns by industry, and consumer prices) is first passed down to the spatial microsimulation model (SpatialMSM), which would be specifically calibrated for the MDB region. The output of SpatialMSM then feeds into STINMOD, a federal tax and transfer payments model of the Australian economy to estimate household income net of tax and transfer payments. STINMOD provides changes in household income cross-tabulated with a number of household variables or characteristics to compute the desired social indicators of the distributional impacts of the water policy reform on the MDB households.

To extend further the distributional analyses of the water policy shock to the changes in social disadvantage of the MDB households, STINMOD is linked in a top down fashion to a Social Impact and Disadvantage Model (SIDMOD). The output of SIDMOD would provide further estimation of a number of key household variables to calculate the social disadvantage indicators for households in the MDB. Finally, it may be desirable to link the social models back to the ecological system via an agent-based model, thus linking all systems directly and via feedback loops.

This paper attempts to develop a useful and practical integrative analytical framework to analyse the macro and structural (CGE models), distributional (microsimulation and agent-based models) and ecological (agent-based models) effects of the water policy reform in the MDB. The ecology- economy-social trade-offs must be so designed that they achieve the objective of restoring the health of the river system in the MDB, with minimum adverse effects on the other systems. The paper outlines a starting point for such an integrative analytical framework. In fact, with adequate investments in water-saving infrastructure and technological innovations, it is possible that in the long run, all the three systems can come out as winners.

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[15] The *AusRegion + Water Trade Model* of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) is another example of a "bottom up" multi-regional multi-sectoral CGE model of the Australian economy, which modelled the MDB to analyse the Basin Plan.

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