Introduction: The Use of Simulation Models in Policy Analysis*

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Abstract
This is an introduction to the papers in this special issue on policy simulations discussing a variety of simulation models. Simulation modelling has become a powerful tool to analyse hypothetical and actual policy changes. This issue contains analyses based on both macro- and micro-level data. The two macroeconomic-oriented papers use a General Equilibrium modelling approach with macro-level data, whereas the three microeconomic-oriented papers use detailed micro-level data to replicate the actual financial situation of Australian/New Zealand households by applying the rules and formulas of the taxation and social security systems for a sample representing the population. This introduction also provides an overview of directions for extension and improvement of models and the development of new types of models, combining micro and macro aspects.

Background
The assessment of policy before implementation is paramount for policy makers. The development of tools to make these assessments is therefore important. In many policy-oriented analyses, use is made of simulation methods to assess/predict the effect changes may have if they were to be implemented. The alternative to using simulation methods is an experimental approach, where a new policy is either partially (for a subgroup of the population) or fully implemented, before analysis can take place. In this approach, data need to be collected just before and after the change and there is a need to control for other changes occurring within the same time frame to assess the policy change of interest properly.[1] This can be complicated to achieve and it is not always desirable to test a new policy in practice.

In contrast, simulation methods make use of patterns of behaviour or relationships between variables that can be observed and estimated from the past and are generalised to predict what effect a new policy change will have. Some simulations are very simple and involve the prediction of a dependent variable from an estimated equation under changed

[1] See for example, Heckman, LaLonde and Smith (1999) for an overview of the methodology and empirical examples.
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circumstances whereas other simulations involve extensive modelling of several relationships or need detailed information regarding the situation before and after the change.

In the papers in this issue, the more extensive type of simulation study is used. We distinguish two varieties of simulation models, macro- and micro-level based models. Macro-level models provide little detail on the individual firms and household in an economy, but they usually model a large number of sectors of the economy and the relationships between the sectors. A disadvantage is that it is often more difficult to understand the effects or examine the effects on subgroups. For example, if there is a decrease in employment how is this distributed across age groups? Micro-level models on the other hand provide a wealth of individual information and changes can be disaggregated to the individual firm or person, but the models are usually limited to one sector of the economy, which means interaction between the sectors is not taken into account. As a result, effects on or limitations resulting from other sectors are ignored.

Micro and macro models are designed to answer different types of questions. For example, if we were to increase social security benefit levels we would need a micro model to inform us about the consequent change in income distribution; however a micro model could not predict any inflationary effects. For this a macro model would be needed. The models described in the papers of this issue are all either micro or macro, but there are developments in the literature combining the two types, trying to make the most of the advantages of each type. I will briefly discuss this literature at the end of the introduction.

Macro-level Simulation Models

Macroeconomic policy models have a long history, starting with Tinbergen (1937), and followed by others such as, for example, Klein (1947), and Klein and Goldberger (1955). Compared to microeconomic models less computer power is required to set up macro economic models, so this type of modelling was feasible at a relatively early stage. In most developed countries, several macroeconomic models have been developed over the past decades helping policy makers to understand and predict the effects of policy changes. Australia is no exception; both in government and at universities macroeconomic models have been developed. Examples are the Murphy Model (Powell and Murphy, 1995) and Treasury's model TRYM (Commonwealth Treasury, 1996).

A related type of model is the general equilibrium model which is developed from input-output models. It tends to be more disaggregated than standard macro-economic models and it often examines long-term outcomes. As noted by Dixon et al. (1992) this type of model looks at the economy as a complete system of interdependent components. This means that economic shocks in one part of the economy can be shown to have repercussions in other areas. The interconnection between different areas of the economy is a major advantage of this type of model. The Centre of Policy Studies (CoPS) is the home of several general equilibrium models, such as ORANI and

MONASH. The relevance of this type of model for policy makers is evident through the many consultancies for State and Federal government in which their models have been used.

The two macroeconomic papers in this issue are both based on a General Equilibrium Model. Groenewold and Hagger use a two-region general equilibrium model to examine the effect of alternative policies on regional unemployment disparities. Each region has three sectors (households, firms and regional government) and there is one common sector for the two regions (federal government). The regions used are Tasmania (as a State with high unemployment) versus the rest of Australia. They find that none of the increases in expenditure can decrease the disparity and that only when federal expenditure was increased in both regions the unemployment rate in Tasmania was reduced. This result indicates that just spending more money on Tasmania will not help to reduce unemployment; other broader policies are needed.

The second paper by Dixon and Wittwer uses a dynamic, multi-regional computable general equilibrium (CGE) model of Australia developed at CoPS, the Monash Multi-Regional Forecasting (MMRF) model, to look at the national and regional impact of a strike in one industry in one State. The MMRF model can include up to 8 regions and 144 sectors (distinguishing different industries). In this particular application, Dixon and Wittwer examine the effect of an industrial stoppage in the Victorian non-residential construction industry on Victoria and the rest of Australia. They look at a variety of economic factors, such as exchange rate, exports and employment, both in the short and longer run. Most effects are short run but there is some flow on to future years as well. The effects are felt in the rest of Australia as well as in Victoria. The authors argue that this type of information could for example be helpful to inform the Australian Industrial Relations Commission of economic damage associated with specific stoppages. The model can account for specific circumstances associated with a stoppage to provide a relevant prediction of the economic damage that would otherwise be difficult to obtain.

Although MMRF can deal with up to 8 regions, in both macro-oriented papers, one of the Australian states is taken versus the rest of the country. Both papers evaluate national and state-wide effects of policy changes. Dixon and Wittwer focus on the effect of one shock to the economy, whereas Groenewold and Hagger explore the effects of four different policies of increasing regional or federal government expenditure. Regarding the analysis of the effect, Dixon and Wittwer look at a range of economic measures whereas Groenewold and Hagger focus on the measure of regional disparities in unemployment. However, both papers allow for interactions between sectors and regions, so that the outcomes reflect interdependencies, which are impossible to obtain from a 'back of the envelope' calculation.

Micro-level Simulation Models

Microsimulation models are used to replicate events in the real world based on a sample from the relevant population on which detailed information at the micro level is available. The models discussed in this issue are all used to examine the effects of hypothetical or actual tax and benefit reforms, using a large cross-sectional data set that reflects the degree of heterogeneity found in the population.[2] Policy changes for which this type of simulation can be done are mostly of a financial type, such as a change in the amount of benefits, the withdrawal rate, eligibility for benefits, or the range of income where a withdrawal rate applies.[3] Such changes result in a change in net income at the observed labour supply in a static microsimulation model, as in the papers by Toohey and Beer, and by Creedy and Tuckwell; or at each of the defined discrete hours points in a behavioural microsimulation model, as in the paper by Creedy and Scutella. In a behavioural model, the changed net incomes may cause a shift in the optimal labour supply choice for an individual, and thus in the individual's behaviour.

The papers in this issue show that a considerable amount of insight can be obtained through the use of static microsimulation modelling. Policy changes may have large (unforeseen) effects on specific subgroups, which can often only be discovered before implementation through the use of extensive microsimulation modelling which mimics the real situation. In this way the often complicated interaction between the social security system and taxation is taken into account.[4]

The relevance of microsimulation modelling in understanding and studying social policy issues has further been shown by the recent series on Tax and Social Security 'Too much tax' by *The Australian*, in which newspaper articles relied on numbers obtained from the microsimulation models of the Melbourne Institute of Applied Economic and Social Research (MIAESR) and the National Centre for Social and Economic Modelling (NATSEM).[5]

In Toohey and Beer's paper, simulations for hypothetical households of a couple with 1 to 3 children at different income levels show the problem areas in the current social security system, where an accumulation of income tax, benefit withdrawal rates and childcare costs can make the effective marginal tax rate (EMTR) very high for groups of married women. They use the measure of Effective Average Tax Rate (EATR), which looks at the proportion of income paid in tax or withdrawn from benefits per additional hour of work instead of per dollar in the commonly used EMTR. When examining work incentives the EATR seems a more relevant measure than the EMTR. Toohey and Beer show that the financial incentive to participate in the labour force or work additional hours is low for married women in

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[2] Although the microsimulation models discussed in this issue all focus on labour supply, taxation and social security issues, this type of model can also be used to study other issues such as the housing market by incorporating the relevant information at the individual level, as is shown for example by the research of Wood, Watson and Flatau (2003).

[3] These contrast with, for example, changes in rules regarding the duration of benefits, residence requirement, willingness to accept training, the ability to refuse job offers, and reasons for job loss. These are important design features of a transfer system, but are difficult to accommodate in a microsimulation.

[4] For example, a change in a benefit may have consequences for other payments which may not be obvious, but are revealed when benefits and taxes are systematically calculated for each individual in the sample as they would be in reality.

[5] This series ran from Saturday 21 February 2004 to Saturday 28 February 2004. Every day, a range of articles on different tax and social security issues was published.

low-income families. The situation is better for high-income families. For families with more children there is a wider income range for which these incentives are low, due to the higher level of family payments.

To ensure policy relevance the base data used in simulations of the aggregate effect of policies need to represent the population of interest accurately. This issue is addressed here by Creedy and Tuckwell, who reweight their sample of the New Zealand population to obtain a better representation of the social security recipient population. Usually weights provided with the confidentialised unit record files do not explicitly correct for under-or over-representation of the population of social security recipients. Creedy and Tuckwell show the number of singles on income support is under-represented whereas the number of couples is over-represented. They use official numbers from the Inland Revenue Department and the Ministry of Social Development to correct this. For policy simulations, this reweighting may be relevant as is shown by their paper. The number of households losing from an increase in income tax rates and an increase in family support payments is overestimated when using the original data. In the reweighted simulation, more people are predicted to gain and fewer are predicted to lose. The distribution of those gaining or losing also changes across the different family types and the type of income support recipient.

Blundell *et al*. (2000) show that behavioural modelling can be important when examining the effects of policy changes. For example, inclusion of behavioural effects (changes in labour supply) in a microsimulation model resulted in a predicted cost of extending Family Credit to the more generous Working Families Tax Credit in the UK that is 14 per cent lower than would have been predicted without allowing for behavioural changes. Creedy and Duncan (2002) provide an extensive discussion of the use of labour supply models in microsimulation. Here we give a brief outline.

Behavioural modelling makes use of the estimated parameters of a model, which describes the relationship between labour supply, wage rate, other income and individual characteristics. The main underlying assumption is that individuals choose a level of labour supply and net income, conditional on the attainable options that optimise their utility. Gross income at the different levels of labour supply is calculated using the relevant labour supply, wage rate and other income. A behavioural model depends on an accurate representation of benefit and taxation rules to calculate what the net income is at all levels of gross income. The model can then be used to predict what the change in a person's labour supply behaviour will be as a result of a policy change. The effect of any policy change affecting the gross to net income transformation can be calculated.

Thus, estimated parameters are used to simulate the effects on labour supply of policy changes.[6] A common approach is to use a base data set and start from the labour supply observed in this data set to obtain a starting point for simulation based on the observed labour supply under a particular tax

[6]Creedy *et al.* (2002) discuss behavioural microsimulation modelling in detail and Creedy and Kalb (2003) provide a briefer discussion. Examples of microsimulation studies are Bingley *et al.* (1995), Scholz (1996), Blundell *et al.* (2000), Bingley and Walker (2001), Duncan and Harris (2002), Creedy, Kalb and Kew (2003), and Gerfin and Leu (2003).

and benefit system. The set of error terms that in combination with the parameters of the labour supply model resulted in the observed labour supply is used to compute a distribution of labour supply after a specified reform.[7] Given an individual's characteristics and draws for the error term, utility at each hours level after the change can be determined. In this way, a probability of being at each of the discrete hours points, conditional on the pre-reform labour supply, can be derived for each individual. Discrete hours models are popular in tax policy microsimulation, because it is relatively easy (compared to the continuous models) to incorporate taxation and social security details. In addition, Van Soest, Woittiez and Kapteyn (1990) and Tummers and Woittiez (1991) show that a discrete specification of labour supply can improve the representation of actual labour supply compared to a continuous specification.

Creedy and Scutella use a behavioural microsimulation model to illustrate the sensitivity of social welfare and inequality measures to different units of analysis. The importance is not so much the absolute values of these measures as is the ranking of alternative situations based on the calculated measures. As long as the relative value of a measure remains similar when using different parameter values (for economies of scale or inequality aversion) or different units of analysis, evaluations of policy changes will not be affected. Creedy and Scutella compare the different predicted outcomes on social welfare and inequality arising from a change from the current system to a system with a basic income and a flat tax when using alternative units of analysis. The results for inequality are unambiguous (it decreases in all cases), but for social welfare the results depend on the choice of units of analysis for low levels of inequality aversion. Using households or equivalent adults (while assuming large economies of scale) results in a reduction of social welfare at low inequality aversion levels, whereas social welfare always increases as a result of the policy change when individuals are used. This highlights the importance of using alternative (specifications of) measures in evaluating a policy to ensure robustness of a particular conclusion. The different specifications of the measures imply different assumptions about for example the economies of scale in larger households. As emphasized by Creedy and Scutella, the choice of the unit of analysis is a subjective choice based on what is the main concern, social welfare or inequality.

After accounting for labour supply changes, inequality is reduced by a larger value but social welfare is increased by a smaller amount, and actually decreases for a wider range of parameter values. The lower increase in social welfare results from a welfare measure that only takes income into account and not the value of leisure or home production time.

The Way Forward: New Developments in Simulation Modelling

The question is how can we combine attractive features from the different types of models and what extensions or improvements of the models described above would be of interest? There are recent developments linking micro and macro models or using features of micro modelling in macro models or vice versa. Dynamic microsimulation is another field of interest,

[7] The more error terms that are drawn, the more accurate is the computed distribution, especially for those points with low probability.

allowing, for example, research into the effects of an ageing population or in life cycle issues, such as the labour force participation of mothers. Finally, how do we evaluate the effects of policy, what measures do we use? I would like to conclude this introduction with a brief overview of these issues.

Linking Microsimulation with Macroeconomic Research

There have been recent developments in a class of dynamic, stochastic general equilibrium (DSGE) macroeconomic models which incorporate heterogeneity among consumers. These models have not been as widely used as the benchmark 'representative agent' DSGE models, but are growing in popularity. A key feature of heterogeneous agent models, which makes them particularly attractive for use in policy research, is that they generate equilibrium outcomes with non-trivial distributions of income, wealth, hours worked, and other variables of interest. This type of model would overcome to some extent the disadvantage of macroeconomic models which do not allow for a heterogenous population and where results cannot be disaggregated to provide more information. In a way, they combine the most attractive features of micro- and macroeconomic modelling: enabling more disaggregated results than standard macroeconomic models and accounting for relationships between different sectors of the economy, which is unavailable in microeconomic modelling.

Early versions of heterogeneous agent models focused on environments in which consumers could not perfectly insure themselves against all idiosyncratic risk, because of liquidity constraints, incomplete markets, or other features. Examples include Imrohoroglu (1989, 1990), Hansen and Imrohoroglu (1992), and Aiyagari (1994). A useful overview of these models is in Ríos-Rull (1995).

More recently, models have been developed that incorporate a much richer degree of heterogeneity among households. Heckman, Lochner and Taber (1998) present a model with overlapping generations of people who have different initial ability levels and different skills acquired through schooling and on-the-job training. The model is used to examine the rising wage inequality. Imrohoroglu *et al.* (1999a, b) present a model with overlapping generations of people who face both mortality risk and individual income risk. These agents also differ in their employment status and asset holdings. The authors use this model to examine the implications of an unfunded social security system and the optimal replacement ratio. Gourinchas and Parker (2002) analyse consumption decisions over consumers' life cycles in a model that features heterogeneity in occupation and education as well as income. Regalia and Ríos-Rull (2001) construct a model with both male and female agents, who make decisions about marriage and childbearing and invest in their children's human capital. They find that this model accounts very well for observed increases in the number of both single women and single mothers in the United States.

These papers give some idea of the range of realistic behavioural and policy issues that can be addressed with DSGE models. Using heterogeneous agent DSGE models in conjunction with microsimulation modelling has other attractions as well. First, the general equilibrium nature of heterogeneous agent DSGE models may provide useful guidance on how best to incorporate dynamic features into microsimulation models. Second, heterogeneous agent DSGE models allow for outside sources of uncertainty. For example, macro models could be used to incorporate business cycle shocks, monetary policy and productivity shocks into microsimulation-based analyses.

Australian researchers who have contributed in this area are for example, Dixon, Malakellis, and Meagher (1995), who set out a framework to use microsimulation results in GE modelling. Bækgaard and Robinson (1997) do the reverse, using macro-level predicted changes to apply appropriate reweighting of the base sample used in a static microsimulation model. The reweighting could reflect for example changes in employment levels resulting from a policy change.

Life-cycle and Behavioural Microsimulation Modelling

Dynamic behavioural microsimulation modelling is extremely computationally intensive, and so far models can only deal with households with relatively few characteristics, which means only a limited amount of heterogeneity can be incorporated in the models. The alternative is to use discrete-time life-cycle models, where transitions regarding partnering, fertility, labour force status, and earnings are simulated at discrete points in time. All decisions in the life-cycle model are simulated using estimated models and are calibrated to reflect actually observed numbers. Projected populations can then be used to incorporate taxation and social security outcomes in microsimulation, allowing some extent of behavioural responses as long as it does not affect the life-cycle decisions.[8]

Even with the simpler discrete form of life-cycle modelling, several issues of interest to government could be examined using a model as described here. For example, allowing calculation of incomes across a lifetime subject to savings rates and to tax and social security rules, so that the accumulation of wealth can be simulated, is necessary to study retirement issues. These savings rates and the tax and social security rules can be changed in the calculations to study the effect of alternative policies. Female labour force participation and fertility are another topic high on the agenda. These topics are of great interest to current policy makers.[9]

Welfare, Poverty and Inequality Measurement

Measures of income changes, poverty, inequality, winners and losers, and marginal effective tax and replacement rates are most often used in evaluation of policies. However, when behavioural simulation outcomes

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[8] The National Centre for Social and Economic Modelling (NATSEM) has developed a dynamic microsimulation model for Australia, which can generate lifetime profiles for individuals (see for example, King, Bækgaard and Robinson, 1999). Other examples are Creedy and Van de Ven (2001) and several publications and models can be found on the website of the Retirement and Income Modelling Unit at Treasury (http://rim.treasury.gov.au/content/default.asp). However, these models do not allow for behavioural responses to policy changes.

[9] Intergenerational issues relating to the ageing of the population featured prominently at *Pursuing Opportunity & Prosperity*, the recent Economic and Social Outlook Conference jointly sponsored by the Melbourne Institute and *The Australian*. Having a tool to analyse the effect of alternative policies will be of great value in addressing these issues.

are evaluated these measures have received relatively little attention in the literature. When using discrete choice labour supply models in simulation, the outcomes of analyses are probabilistic in nature. Measures of inequality or poverty which can deal with these probabilistic outcomes need further development.[10]

To go beyond the traditional measures of poverty or inequality when using behavioural modelling, welfarist approaches of money metric compensating and equivalent variations (CV and EV) could be used to assess both financial and non-financial gains (or losses) to social welfare. In the case of a utility decrease after a policy reform, the CV can be viewed as the minimum amount of income one would need to give the household in order to keep it at the same level of utility it had before the tax policy change, whereas the EV can be interpreted as the amount of money a household is willing to pay not to be subjected to the policy reform.

Once the CVs/EVs are obtained, a variety of well established social welfare functions can be applied in order to assess the impact of a tax policy change. A significant aspect of using CVs/EVs is that they can account for non-monetary benefits, or quality of life aspects. To illustrate this point, consider a tax policy change that would lead to a reduction in working hours by both men and women. Clearly, from an income perspective, this measure would be 'bad'. However, using a utility measure, in which extra leisure time is valued, it may be good. Despite their intuitive appeal and direct applicability, these welfare measures remain under-investigated in papers using (discrete) labour supply models, partly due to difficulties generated by the highly nonlinear budget constraints.[11]

A shift in focus to a more encompassing measure of welfare may be welcome to policy makers who often remark on the fact that economists only look at income and ignore non-monetary issues (such as leisure or time available to spend with the family).

Conclusion

The papers included in this special issue provide a broad overview of simulation models that are currently available in Australia and New Zealand. They illustrate the important contribution this research can make to informing policy makers and consider some methodological issues associated with this type of research.

There is a role for both micro and macro models, which are designed to answer different types of policy questions. Macro models can examine effects on an aggregate level which are dependent on what happens as a result of a change in different sectors of the economy. For example, employment depends on the effect of a proposed change in the sector of firms and the sector of households. Micro models, on the other hand, can

[10] Creedy, Kalb and Scutella (2004) propose an approach for calculating inequality and poverty measures in a discrete choice microsimulation setting, which was applied in the paper by Creedy and Scutella in this issue.
[11] Creedy and Kalb (2001) suggest an approach to measure welfare in these circumstances.

provide an in-depth analysis of one sector of the economy, disaggregating an effect at the national level to effects at the individual level, showing for example distributional effects. Micro and macro models are complementary and should be used in combination rather than in place of each other. Ideally new developments in modelling would combine aspects from the two types of model.

The research in this area is continuously developing and there are several exciting new opportunities to extend and improve existing models and develop new types of models.

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