Linking a Dynamic CGE Model and a Microsimulation Model: Climate Change Mitigation Policies and Income Distribution in Australia*

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* This paper uses CGE Modelling from the Garnaut Climate Change Review as inputs into the Melbourne Institute Tax and Transfer Simulator (MITTS) to disaggregate economy wide macro level results into results at the household and individual level. However, this work is not part of the Garnaut Report and is not endorsed by the Garnaut Review. All responsibility for the specification and outcomes of this work lies with the authors and all questions regarding this should be directed to them. However, we would like to thank Ana Markulev, Helen Morrow, Jonathan Chew, Philip Adams, Matthew Clark, Naomi Lewis, Jyothi Gali and Nicholas Stoney for their comments, suggestions and help in using the CGE output.

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Abstract

This paper extends the 'top-down' framework, introduced by Robilliard *et al.* (2001), to link a computable general equilibrium (CGE) model to a microsimulation model. The proposed approach allows the linking of a microsimulation model to a dynamic, and not simply a static, CGE model by enabling the microsimulation model to reproduce the predicted long-term changes in the base population. The approach relies on altering the sample weights in order to reproduce population projections and the changes in employment as estimated by the CGE model. A particular effort is made to discuss the limitations arising from the various assumptions made in both models as well as in the linking process. As an illustrative example, the approach is applied to assess the effects of climate-change mitigation policies in Australia from 2005 to 2030 at five-yearly intervals.

1. Introduction

This paper outlines an approach to disaggregate the results of a dynamic economy-wide computable general equilibrium (CGE) model into results at the household and individual level by using a microsimulation model. The proposed approach is applied to predict the effects of climate-change mitigation policies on income and inequality in Australia for the period from 2005 to 2030.

The proposed approach draws on the 'top-down' framework introduced by Robilliard *et al.* (2001) in which the CGE model is run in a first step and the changes are passed on to the microsimulation model in a second step. However, in order to transmit employment changes from the CGE to the microsimulation model, a reweighting procedure is used instead of the behavioural component of a microsimulation model. This alternative approach is preferred in the dynamic framework because it is then straightforward to incorporate the benchmarks required to reproduce the demographic changes predicted to occur in the base population over the relevant period of analysis.[1]

The focus of the paper is on the methodology developed to link a dynamic economy-wide CGE model, the Monash Multi-Regional Forecasting (MMRF)-Green model (see Adams *et al.*, 2002, 2007), to a microsimulation model, the Melbourne Institute Tax and Transfer Simulator (MITTS; see Creedy *et al.*, 2002). The paper provides an overview of the relevant assumptions made in both models as well as in the linking process. In addition, it discusses the limitations of the modelling approach and the initial discrepancies between the two models. As an illustrative example, the approach is applied to assess the effects of climate-change mitigation policies in Australia from 2005 to 2030. The CGE model used in this paper was developed as part of the Garnaut Review on climate change. The CGE results are used as exogenous inputs in our analysis. That is, the CGE results are a given in this paper and the aim is to make the best possible use of the microsimulation model to produce estimated effects on income distribution. Therefore a brief description of MITTS is provided in Section 2 while the CGE model and assumptions are only discussed where relevant to MITTS.[2]

The structure of the paper is as follows. Following the description of MITTS in Section 2, a detailed discussion of the linking approach is given in Section 3. Section 4 presents the results on income for the reference case and the two mitigation scenarios. Section 5 concludes.

[1] Ferreira and Horridge (2006) present a reweighting approach to link a static CGE model to a household survey. However, it differs from the approach presented here in many aspects. See Hérault (2009) for a comparison of both approaches.

[2] See Garnaut (2008) and the accompanying technical papers for a discussion of the CGE modelling. The main assumptions in MMRF-Green are summarised in Appendix A (Table A.1).

2. The Melbourne Institute Tax and Transfer Simulator

MITTS is a behavioural microsimulation model, but for this analysis only the non-behavioural component is used.[3] The employment changes predicted by MMRF-Green, as well as the changes in the base population, are reproduced using a reweighting procedure in MITTS. This component imputes net household incomes for a representative sample of households, for both incumbent and counterfactual tax-benefit regimes. A major advantage of microsimulation modelling is that such modelling retains the full extent of the heterogeneity contained in the survey data used.

This subsection first describes the arithmetic microsimulation model, followed by a discussion of the data required to build this type of model (see Creedy *et al.,* 2002 for more details).

2.1 The Arithmetic Model

When examining the effects of policy changes, these models generally rely on tabulations and associated graphs, for demographic groups, of the amounts of tax paid (and changes in tax) at various percentile income levels. The more sophisticated models may have extensive 'back end' facilities allowing computation of a range of distributional analyses (such as the Gini coefficient) and tax progressivity measures, along with social welfare function evaluations in terms of incomes. Arithmetic models are typically used to generate profiles, again for various household types, of net income at a range of gross income levels.

Since the first version was completed in 2000, it has undergone a range of substantial developments and data updates. In the present version of MITTS, the Survey of Income and Housing Costs (SIHC) data from 1994/1995, 1995/1996, 1996/1997, 1997/1998, 1999/2000, 2000/2001, 2002/2003 and 2003/2004 can be used. Results are aggregated to population levels using the household weights provided with the SIHC.

In MITTS, the arithmetic tax and benefit modelling component is called MITTS-A. The tax system component of MITTS contains the procedures for applying each type of tax and benefit. Each tax structure has a data file containing the required tax and benefit rates, benefit levels and income thresholds used in means testing. In view of some data limitations of the SIHC, it is not possible to include within MITTS all the complexity of the tax and transfer system. However, all major social security payments and income taxes are included in MITTS.[4]

Pre-reform net incomes at the alternative hours levels are based on the MITTS calculation of entitlements, not the actual receipt. In the calculation of net income it is assumed either that

[3] The majority of large-scale tax simulation models are non-behavioural or arithmetic. That is, no allowance is made for the possible effects of tax changes on individuals' consumption plans or labour supplies.
[4] For details of the different payments, see Payment Guides published by the Commonwealth Department of Family and Community Services (of several years), DVA Facts and the annual report published by the Department of Veterans' Affairs (of several years).

take-up rates are 100 per cent, or a simple rule is used whereby a benefit is not claimed if it is less than a specified amount. The version of MITTS used in this paper assumes a 100 per cent take-up. This is likely to cause overestimation of government expenditure on some of the payments. It is argued that when interest is in the differences from the reference case, this approach is quite satisfactory. Both the amounts in the reference case and in the mitigation scenarios will be overestimated, and the predicted percentage differences are expected to be informative. Furthermore, in this paper it is assumed that benefit rates and benefit threshold incomes remain the same in real terms. However, alternative tax and transfer systems are still required in this analysis to account for the indexation of income tax thresholds to real wages.

The various components of the tax and benefit structure are assembled in the required way in order to work out the transformation between hours worked and net income for each individual under each tax system. For example, some benefits are taxable while others are not, so the order in which taxes and transfers are calculated is important.

2.2 The Data

The distinguishing feature of microsimulation models is the use of a large cross-sectional dataset giving information about the characteristics of individuals and households, including their labour supply, earnings and (sometimes) expenditure. Microsimulation models are therefore able to replicate closely the considerable degree of heterogeneity observed in the population. The two large-scale household surveys that are potentially useful are the Household Expenditure Survey (HES) and the SIHC. The former does not contain sufficient information about hours worked by individuals while the latter does not contain information about expenditure patterns. The SIHC is a representative sample of the Australian population, containing detailed information on labour supply and income from different sources, in addition to a variety of background characteristics of individuals and households. The measurement of income in the HES is known to be unreliable, so that in developing models for the analysis of direct taxes and transfer payments, it is not surprising that reliance has been placed on the SIHC.[5]

When analysing actual or proposed policy changes, it is preferred to use data which are as close to the relevant time period as possible to avoid having a starting point that is too different from reality. When this is not possible, MITTS updates all financial information to the relevant year; that is, for example, in our analysis the amounts of income in 2003/2004 are increased to reflect January 2006 amounts or January 2010, 2015 etc. amounts. To update non-labour incomes, the Consumer Price Index (CPI) is used. To update wage rates, the average male and female wage indices are used for 2005, while MMRF-Green regional wage

[5] The survey of 2003/2004, which we use in the analysis, is uncommon in that it actually combines these two data sets, and these data would in fact be ideal to develop a consumption model together with a labour supply model. However, this combination of the two surveys will not be a regular feature; the next combined data collection is planned for 2009/2010 (ABS, 2007).

indices are used in subsequent years. Wage indices usually increase at a faster rate than the CPI.

3. Linking MITTS to MMRF-Green: Methodology

The variables used in making the link between the CGE model MMRF-Green and the microsimulation model MITTS are central to the analysis in this paper. All variables from the CGE model affecting the structure of the Australian population, household incomes or expenditures are relevant. Households derive most of their income from labour market activities, so any changes affecting wages or employment are particularly important. In addition to transferring this information for each point in time considered (that is, years 2010, 2015, 2020, 2025 and 2030) and for each policy run, MITTS needs to replicate the assumptions made by MMRF-Green about the evolution of the population and the labour force.

3.1 Population and employment changes: the reweighting approach

The Australian population is not explicitly modelled in MMRF-Green. Instead, changes in the population as predicted by Treasury (Commonwealth of Australia, 2008; Commonwealth Treasury, 2008) based on Australian Bureau of Statistics (ABS) data (2005, series B) are used to derive changes in the labour force, which in turn determine changes in labour supply. Treasury predicts the Australian population by age and gender up to 2050 starting from ABS (2005, series B) projections for the Australian population by age, gender and region up to 2050. However, the Treasury projections diverge from the ABS projections over time. Treasury's projections form the base of the underlying population projections in MMRF-Green. ABS projections are only used in order to derive regional populations using the projected ABS proportions by region together with the Treasury projections, since the latter are only available at the national level.

We use State population sizes as predicted by MMRF-Green. State populations are the same across the reference case and the two scenarios, but they vary over time through interstate migration and population growth.

MMRF-Green also estimates changes in employment levels by industry and region in a general equilibrium framework. The assumption in the CGE modelling is that employment levels by industry and region are determined by the model (that is, they are endogenous to the model) and the long-run rate of unemployment is assumed to be fixed. Since the industry classification is more aggregated in MITTS than in MMRF-Green, the changes in employment by industry provided by MMRF-Green are combined into 13 industry groups which are identifiable in MITTS.[6] In addition, MMRF-Green provides the number of unemployed persons by region.

[6] See Buddelmeyer *et al.* (2008) for a description of the mapping process.

The base file used in the microsimulation analysis is the ABS 2003/2004 SIHC, which has been updated to the financial year 2005/2006 within MITTS using the CPI to inflate incomes and male and female wage indices to adjust wage rates. MITTS needs to be benchmarked based on the information from MMRF-Green so that the initial population and labour force in the starting year in MITTS are consistent with MMRF-Green. In addition to reweighting these data for the base year, the base file used in MITTS needs to be reweighted separately for every year for which a simulation is run, benchmarking the MITTS input data against MMRF-Green output to reproduce the required employment and population changes over time. A reweighting approach is used to map the base levels and changes as predicted by MMRF-Green to the MITTS environment. This approach relies on adjusting the household weights in the SIHC so that changes in the relative and absolute size of various subgroups of the population are accounted for.

Consistency between MITTS and MMRF-Green is ensured in two reweighting steps as explained below. The structure of the population by age, gender and region provided by Treasury+ABS projections is altered by the interstate migration as predicted by MMRF-Green. This results in differing regional composition of the population by age and gender. Hence, MITTS cannot be benchmarked to both projections.[7] Ideally, MITTS should be benchmarked to MMRF-Green but the information available from MMRF-Green is too aggregated to provide MITTS with a sufficiently detailed description of the Australian population. Instead, the approach used first ensures consistency with Treasury+ABS population projections and then in a second reweighting step ensures consistency with MMRF-Green's employment and unemployment projections and updated interstate migration estimates.

In the first step, the underlying MMRF-Green population projections are imposed on MITTS using Treasury population projections, supplemented by the ABS regional decomposition (2005, series B). This is achieved by reweighting our basic sample from 2003/2004 to reflect updated benchmarks in terms of age and gender by region as predicted by Treasury+ABS.

Following the approach by Deville and Särndal (1992), Cai *et al.* (2006) reweighted a base file in MITTS, and the same approach is used here. In order to calculate the new weights, benchmarks from the Treasury and ABS are used; these include the population size and composition by age, gender and region. The reweighting approach aims to achieve specified population totals for selected variables, subject to the constraint that the adjustments to the original weights are as small as possible. Technical details are provided in Appendix B.

In the second step, the reweighting takes into account changes in employment levels by industry and region, unemployment levels by region, and interstate migrations as estimated by

[7] In addition, it should be noted that even if MMRF-Green was fully consistent with Treasury+ABS projections, two steps might still be required since there are limitations on the number of constraints that can be used in calibrating the new weights.

MMRF-Green. Employment levels in MITTS are benchmarked against employment levels by industry and region in MMRF-Green using the same reweighting procedure as in the first step. As explained above, MMRF-Green industries are grouped so that they can be mapped to the 13 industries distinguished in MITTS. The reweighting process is based on a number of constraints (representing the various benchmarks with regard to employment, unemployment and State populations) which ensure that MITTS reproduces the changes predicted by MMRF-Green in terms of interstate migrations, and employment and unemployment levels by region.

However, imposing all these constraints while not controlling for continued consistency with the Treasury projections could result in substantial discrepancies. For example, reweighting with regard to unemployment levels could affect the structure of the total population by age and gender since the unemployed are likely to have different characteristics compared to the rest of the population. To avoid such discrepancies, benchmarks for age and gender composition at the national level are also imposed at the second stage of the reweighting. Although these constraints ensure that MITTS remains consistent with the Treasury population projections by age and gender at the national level, in practice, discrepancies can still occur at the regional level. This is the case essentially because Treasury+ABS projections are altered by MMRF-Green, but MMRF-Green does not provide information about the new age and gender structure of regional populations. The two-step reweighting approach ensures that MITTS is consistent with MMRF-Green and that the deviations between MITTS and Treasury+ABS projections are minimal.

3.2 Labour and non-labour incomes

In the base year of 2005/2006, MMRF accounts for wage differences by industry and region. In policy runs, the wage rates for different industries are presumed to move proportionally, that is, the pre-existing wage differential between industries is held constant. However, regional wage differentials are assumed to be flexible. As a result, MMRF-Green generates changes in average wages by region but not by industry (nor occupation). This has the disadvantage that there is no opportunity for skill levels to affect wage growth in MMRF Green, and therefore current wage differentials between low- and high-skilled individuals are held constant in relative terms. Therefore, the information transferred to MITTS cannot account for changing wage differentials by skill level, which would otherwise have been likely to contribute to changes in income inequality.

The information on income in MITTS is very detailed. Information on all income components is available either at the household or individual level. In MITTS, labour income is determined at the individual level whereas MMRF-Green only estimates average changes in wages by region. The average changes estimated by MMRF-Green concern gross wages and these are used to update gross hourly wage rates in MITTS.

Similarly, information about non-labour income is only available at the regional level in MMRF-Green. In addition, the various non-labour income components are aggregated into two broad components: (i) non-labour factor income (mainly capital income), and (ii) individual benefit payments from the government with four subcategories: unemployment, disability, age and other. Following MMRF assumptions, all individual benefit payments in MITTS are indexed to the CPI in order to be held constant in real terms.

The use of updated gross wages and non-labour income, combined with observed labour supply for each individual, enables the calculation of income tax and social security payments using the tax and social security system of January 2006 (this is in the middle of the base financial year used in MMRF Green).

Since MMRF-Green only generates average changes by region, the average change corresponding to their region of residence is applied to each household in MITTS. The four components of non-labour income available in MITTS, which include income from own unincorporated business, total income from investments, income from child support or maintenance, and other regular payments, are increased (or decreased) by the same percentage as predicted by MMRF-Green.

Since individual benefit payments from the government are fixed in real terms in MMRF-Green, the same assumption is made in MITTS.[8] However, changes in individual benefit payment levels can still occur at the individual level because eligibility to all individual benefit payments is determined endogenously by MITTS taking into account gross incomes. MITTS only uses gross income (both labour and non-labour income) from households as an exogenous input, from which it calculates income tax paid and income support received according to a set of taxation and social security rules. These rules are programmed in MITTS and can be changed to accommodate policy changes. The rules usually vary by household composition (also exogenous to the model). Using gross income combined with the computed amounts of income tax and income support payments, net income can be calculated.

Only income changes in real terms are used so that other eligibility criteria do not have to be updated to account for inflation. However, income tax thresholds are indexed to real wages in order to hold the national average tax rate constant, in accordance with MMRF-Green assumptions.[9]

Tax and transfer microsimulation models are particularly strong on the calculation of net (or disposable) income starting from individuals' gross incomes. As a result, establishing the link with the MMRF-Green model then allows for the calculation of individuals' gross incomes —

[8] This is different to the current practice where allowances such as NewStart or Sickness Allowance are indexed using the CPI, but pensions, such as the Disability Support Pension, and Parenting Payment Single are indexed using wage indices (which usually increase by more than the CPI).

[9] Fixed income tax thresholds would lead to a substantial increase in the average income tax rate since real wages increase over time.

based on their wage, labour supply and other non-labour income—, total income tax and social security payments. Therefore, it is possible to calculate households' disposable incomes under each of the policy runs. Real incomes adjusted for household-specific consumption patterns are computed for each scenario and the reference case, using price and consumption changes from MMRF-Green and the information from the Household Expenditure Survey (HES). Net incomes are expressed in 2005/2006 or base year prices. Table 1 describes the approach used in calculating household-specific CPIs. The cumulative price changes combined with the previous period's budget shares are used. This approach accounts for changes in consumption patterns over time.[10]

Table 1 Computation of household real income for one particular household

	2005 (base)	2010	2015	2020	2025	2030
Nominal household income	y0	y1	y2	y3	y4	y5
Cumulative price changes (63x1 vector)		P1	P2	P3	P4	P5
Budget shares (63x1 vector)	B0	B1	B2	B3	B4	B5
Real household income	y0	$\frac{y1}{B0'.P1}$	$\frac{y2}{B1'.P2}$	$\frac{y3}{B2'.P3}$	$\frac{y4}{B3'.P4}$	$\frac{y5}{B4'.P5}$

The impact on real disposable income per adult equivalent and on inequality (as measured by the Gini coefficient) for each of the policy scenarios over time is considered by income quintile and household type.[11] Income quintiles are determined at the income unit level where each of the five quintiles contains 20 per cent of all income units, but possibly more or less than 20 per cent of the population, depending on the average income unit size in each quintile. Income quintiles are based on the ranking of income units according to real disposable income per adult equivalent using the Whiteford equivalence scale (Binh and Whiteford, 1990).[12] New income quintiles are computed for each year of the analysis since it cannot be assumed that income units belonging to a particular quintile will still belong to the same quintile five years later. In addition, income quintiles differ across scenarios because changes in incomes and employment are different across scenarios.

[10] Using only the budget shares of the base year is clearly unrealistic because it ignores changes in consumption patterns over time as predicted by MMRF. Using the current budget shares is not more appropriate because it would imply a 'double counting' of the price effects (via their effects on consumption patterns, on top of the price effects). Alternatively, average budget shares from all previous points in time could be used. The use of the budget shares from the previous point in time is preferred because it indicates who would have been most affected by a change before behaviour was adjusted.

[11] The advantage of using microsimulation modelling is the substantial flexibility in the way the results can be broken down. In practice, the results can be broken down by any of the household characteristics available in the household survey on which the microsimulation model is based.

[12] The weight of the first adult in each income unit is 1. The weight of each additional adult member is 0.56, and each child (under 18) is given a weight of 0.32.

3.3 Price and consumption changes

MMRF-Green distinguishes 63 different commodities.[13] The relative prices of the 63 commodities are endogenous and may change over time. Moreover, these changes may differ from one region to another and from one policy run to another. Price changes by commodity from MMRF-Green are used to compute household-specific CPIs. As already mentioned in Section 3.2, the latter are utilised to deflate household nominal incomes so that household real incomes are computed while accounting for the specific consumption pattern of each household. This is an important aspect of the approach because price changes will affect households differently depending on their consumption pattern.

The consumption patterns (on which household-specific CPIs are based) also change over time and across policy scenarios. Households' behavioural responses in consumption are driven by changes in relative prices as well as changes in disposable income. Given that MITTS does not model consumption, these consumption changes are determined by MMRF-Green at the regional level and used as input into MITTS. While households in MITTS still have different consumption patterns (derived from consumption as observed in 2003/2004), changes in consumption from year to year only differ by region as predicted by MMRF-Green.

3.4 Tax and social security system

In MMRF-Green, the same income tax rate is applied to all representative households. In the base year, the income tax rate is equal to the average national income tax rate. This income tax rate is held constant over time and across the scenarios.

Since MMRF-Green is based on the 2005/2006 financial year, the tax and social security system of January 2006 is used in MITTS. Given that there is no change in the tax and social security system in MMRF-Green over time, the same assumption is made in MITTS to ensure consistency between the tax and social security system assumed in MMRF-Green and in MITTS. The only exception is the indexation of income tax thresholds to real wage changes in order to hold the average tax rate constant.

3.5 Consistency of aggregate amounts in MMRF-Green and MITTS

This section provides a comparison of income components (labour, non-labour, benefits) as predicted and used in MMRF and MITTS respectively. First, it should be noted that full consistency cannot be expected given that MITTS and MMRF-Green draw on different sources of information. While MITTS is based on a household survey (the 2003/2004 SIHC), the base values in MMRF-Green are derived from various sources, including National Accounts, and Supply and Use Tables.

[13] See Buddelmeyer *et al.* (2008) for an overview of these commodities and a description of the mapping of the commodities distinguished in HES into the MMRF-Green commodities.

The main components of household income in both models are presented in Table 2. A few remarks can be made. First, non-labour factor income is overestimated in MMRF-Green because it includes a large share of 'enterprise income' (because taxes on enterprises are paid by households in MMRF-Green) as well as imputed rents. Hence, a substantial proportion of non-labour factor income appearing in MMRF-Green is actually not returned to households (or not returned in the year it is earned). This explains why total income and disposable income are much higher in MMRF-Green than in MITTS.[14] Since non-labour factor income is more likely to be present in high-income households than in low-income households, this implies that income in higher-income households is more likely to be underestimated in MITTS as a result of this than income in low-income households. Likewise, the estimate for total household consumption is much lower in MITTS than in MMRF-Green.

Table 2: Household income (in millions of dollars)

2005/2006 financial year	MMRF	MITTS
Total household income	886,422	562,478
Labour	447,962	371,716
Non-labour factor income	361,125	121,770
Individual benefit payments	77,336	68,992
Unemployment benefits	5,665	5,758
Disability support pension	8,257	7,148
Age pension	21,407	22,477
Other individual benefit payments	42,007	33,609
Direct taxes on individuals	114,624	113,795
Direct taxes on enterprises	45,435	NA
Household disposable income	726,363	448,683
Household consumption (2003/2004 prices)	543,152	381,155

Second, estimates for total labour income in MMRF-Green are higher than in MITTS because they include employer social contributions, which are not included in MITTS. In addition, labour (and non-labour) incomes are usually underestimated in household surveys. Third, estimates of total individual benefit payments and its various components are similar in MMRF-Green and MITTS; they are only somewhat lower in total in MITTS than in MMRF-Green. Finally, total income taxes paid by households are very similar in the two models.

[14] It should be noted that total household consumption to be used with MITTS is reported in 2003/2004 prices. It would have to be increased by 5.4 per cent (comparing the March 2004 CPI to the March 2006 CPI) to account for inflation between 2003/2004 and 2005/2006. This would assume that household consumption was fixed in real terms during this period. To make MMRF and HES consumption figures fully comparable, HES consumption would need to be further inflated to account for the increase in real incomes between 2003/2004 and 2005/2006, and changes in saving rates should be taken into account. However this is not the focus of this paper.

3.6 Overview of assumptions and limitations

Since the distributional analysis uses the MMRF-Green data as input, any assumption or limitation within MMRF-Green equally applies to the distributional analysis. A second point to emphasise is that although the distributional analysis is based on unit record data for individual households, and is therefore very flexible, this flexibility cannot be fully utilised in all the analyses. For example, changes in wages are available only at a highly aggregated level in MMRF-Green (changes in wages only differ by region). As a result, although the full heterogeneity of the Australian population is accounted for, the same changes over time predicted by MMRF-Green are applied to large groups of households. So for wages, all households within the same region have the same percentage wage increase. The use of microsimulation may create an illusion of more data variation than there is in reality, due to the dependence on MMRF-Green results for changes over time.

Third, the MMRF-Green model does not distinguish between skilled and unskilled workers, which is a limitation with regard to wage and employment developments. Fourth, the assumption that all benefit payments are indexed to the CPI leads by construction to the outcome that all benefit recipients experience zero real income growth. As a result, since wage earners are predicted to experience income growth due to the higher wage index, predicted inequality in Australia increases by design. If benefit payments were indexed to the wage index, the increase in inequality would have been lower. Nevertheless, inequality would probably still have increased to some extent due to an increase in factor income which is more likely to be received by households in the higher income quintiles. Finally, several assumptions are needed since in 2008 the real world from 2009 onwards is basically unknown and becomes more uncertain in the more distant future.

Appendix C gives an overview of a range of assumptions and important limitations in bullet point format.

4. Microsimulation Results

Three scenarios are considered in the simulation. Following the CGE modelling, it is assumed that climate change itself will not have a direct economic impact before 2030. Therefore, the reference case up to 2030 is a projection starting from the current situation without taking into account the possibility of any economic impacts of climate change. The economic outcomes for two alternative mitigation policy scenarios are compared to the outcomes in the reference case. The only difference between the two mitigation scenarios and the reference scenario is the introduction of an Emissions Trading Scheme on 1 July 2013. As a result, all scenarios are identical prior to this date. The two mitigating scenarios are (Garnaut, 2008):

- Scenario 1 involves reducing emissions for Australia to a level of 80 per cent below 2000 levels by 2050 as part of a coordinated global effort to stabilise carbon dioxide equivalent concentrations at 550 ppm by 2100 (the 550 ppm stabilisation scenario); and

- Scenario 2 involves a reduction to 90 per cent below 2000 levels by 2050 as part of a coordinated global effort to stabilise carbon dioxide equivalent concentrations at 450 ppm by 2100 (the 450 ppm stabilisation scenario).

Before discussing the microsimulation results for our illustrative example over time and across the two scenarios in comparison to the reference case, the first subsection checks the transmission of changes from MMRF-Green to MITTS for the reference case.[15] Section 4.2 discusses the effects on income distribution. All income and other financial information is presented in financial year 2005/2006 dollars.

4.1 Comparison of Aggregate Changes

The effects of the changes over time (for example in the wage rate) are calculated separately for each individual in a sampled household. These individual effects are aggregated to the population level through use of the sample weights. Household size, structure and income level, as well as the age, gender and income level of individual household members are observed at the individual level in the sample. Therefore, it is possible to aggregate the individual results by any of these characteristics to obtain the effects for a number of subgroups in the population.

The aggregate results in terms of total household income, taxes and benefit payments, employment and budget shares are reported in Table 3 for the reference case.[16] There is a slightly higher income growth according to MITTS compared to MMRF-Green, and this difference accumulates over time. This may be due to the fact that MMRF-Green predicts an average wage growth by State only, which is then applied to all individuals in that State independent of their current wage level. However, at the same time the structure of employment changes as well (that is, employee numbers by industry). These changes are also transferred from MMRF-Green to MITTS through reweighting of households. It is likely that higher wage industries experience larger increases in employee numbers than lower wage industries. Given that the wage growth predicted by MMRF-Green includes both an increase in wage levels for different types of employees and this change in employment structure, MITTS is likely to double count some of the wage growth by applying the full wage growth and the new employment structure.[17]

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[15] Consistency checks are only reported for the reference case, but similar patterns are found for the two policy scenarios. See Buddelmeyer *et al.* (2008) for more detail.

[16] This section discusses the changes. See Section 3.5 to compare MMRF-Green and MITTS base values.

[17] If wage growth were available by skill level this issue would be less relevant.

Income growth is expected to be particularly strong between 2005 and 2010, while it is expected to slow down between 2010 and 2015.[18] Growth is expected to increase again after 2015. Employment increases steadily over time at a slightly higher rate than the increase in the population size. Benefit payments exhibit a much slower growth than the other income components. Furthermore, this growth is entirely due to the increase in population size and the changing structure of the population, since the assumption made in MMRF-Green is that benefit payments are indexed to the CPI. In other words, benefit payments are fixed in real terms for all benefit recipients. Given that gross incomes grow at a faster rate than the CPI, the share of benefit payments in household incomes is declining over time. This is the main explanation to the substantial increase in overall inequality discussed in Section 4.2 because low-income households rely much more on benefit payments than high-income households. Finally, the average tax rate on labour income in MMRF-Green is fixed at 25.6 per cent. Table 3 shows that the average tax rate calculated from MITTS results follows this rather closely. As explained in Section 3.4, this result is obtained in MITTS by indexing income tax thresholds to real wages.

Table 3 Aggregate income results: Reference case

	2005 (base)	**2010**	**2015**	**2020**	**2025**	**2030**
	$m/year	**Cumulative percentage changes**				
Gross income	494,341	23.9	39.8	59.7	82.5	106.4
Benefit payments	65,936	1.0	8.6	16.9	25.5	34.1
Income taxes + Medicare levy - rebates	123,195	24.0	39.1	57.8	79.7	102.7
Net income	440,137	20.3	35.0	53.4	74.3	95.9
Gross income + benefits	560,277	21.2	36.1	54.7	75.8	97.9
Gross income + benefits (MMRF)	*886,422*	*20.9*	*33.4*	*49.6*	*68.6*	*88.7*
Employment in 1000s (MMRF)	*10,058*	*12.4*	*20.0*	*25.9*	*31.2*	*36.4*
Basic necessities (MMRF)[(a)]	*48.4*	*-1.4*	*-2.8*	*-4.6*	*-6.2*	*-7.7*
Energy bundle (MMRF)[(a)]	*11.6*	*-0.1*	*-0.5*	*-1.2*	*-1.7*	*-2.2*
			Percentage			
Average tax rate	24.9	24.9	24.8	24.6	24.5	24.5
Benefit payments/ Gross income	13.3	10.9	10.4	9.8	9.2	8.7

Note: (a) Aggregate budget shares at the national level (in per cent). Changes are expressed in percentage points.

To ensure consistency with MMRF-Green, two types of lump sum transfers are included in households' incomes in MITTS. The first lump sum transfer is a government handout or tax, which is required in MMRF-Green to preserve the balance of the government's budget as a fixed percentage of GDP. As a result, this lump sum transfer could be negative, implying a transfer from households to the government (a lump sum tax), but overall the lump sum transfer is positive and increases over time. The second lump sum transfer redistributes the carbon permit revenue generated by the introduction of the Emission Trading Scheme (ETS) as calculated in MMRF-Green. For both lump sums, the assumption made in MITTS is that

[18] The global financial crisis has not been taken into account in the CGE predictions, which predate the 2008 financial crisis.

both are equally distributed across the entire population on a per capita basis.[19] The levels of these transfers are reported in Table 4. Of course, this is just one way of redistributing these transfers.

Table 4 Lump sum transfers to households (amounts in $ per year per capita)

		2005	2010	2015	2020	2025	2030
Government handout/tax	Reference Case	0	274	475	855	1,149	1,411
	Scenario - 550ppm	0	274	303	546	760	948
	Scenario - 450ppm	0	274	190	437	650	845
Exogenous change in household income from carbon permit revenue	Reference Case	0	0	0	0	0	0
	Scenario - 550ppm	0	0	495	584	663	699
	Scenario - 450ppm	0	0	727	844	928	939
Total transfer	Reference Case	0	274	475	855	1,149	1,411
	Scenario - 550ppm	0	274	798	1,130	1,423	1,647
	Scenario - 450ppm	0	274	917	1,280	1,577	1,785

The levels of these lump sum transfers to households are of particular importance to low-income households. The choice of how to distribute this revenue is a political choice. An alternative approach to the redistribution would be to distribute the lump sum transfer mostly or entirely to the lowest income households, which would have the effect of reducing income inequality and could be of interest. The lump sum transfer to balance the government's budget is substantial. In 2030, the total amount in the reference case is close to 40 billion dollars, expressed in 2005 dollars. It is somewhat lower in the two mitigation policy scenarios, where it is close in value to the carbon permit revenue. It seems likely that the government would change taxation or social security payments, or introduce other schemes instead of distributing non-taxable lump-sum amounts to households. This is an issue that could be investigated in future studies, making alternative assumptions in the microsimulation modelling and possibly in the CGE modelling as well.

4.2 Income effects

The changes in average real net income (RNI) per adult equivalent by income quintile[20] and household type are presented in Figures 1 and 2 (the corresponding tables are presented in Appendix D).[21] The mitigation policies are not introduced until 2013, which is why the

[19] For each year, the values provided by MMRF-Green on the aggregate lump sum amounts are divided by the corresponding population sizes to obtain the lump sum transfers per capita. These per capita lump sum amounts are then added to that year's net income of the individuals and households.

[20] Income quintile 1 represents the 20 per cent of income units with the lowest equivalised income unit net incomes and income quintile 5 represents the 20 per cent of income units with the highest equivalised income unit net incomes.

[21] Real net income is gross income plus government transfers minus income tax adjusted for inflation, using the household-specific CPIs as described in Table 1 in Section 3.2. Income units are used to construct the quintiles but each individual in the income unit is used to calculate the average real net equivalised income. For example, the bottom quintile is constructed by selecting the 20 per cent of income units who had the lowest real net

reference case and the two scenarios coincide in 2005 and 2010. The strong income growth between 2005 and 2010 is followed by a slowdown (between 2010 and 2015), after which the increase picks up again although not to the extent of the increase in the first five years.[22] The slowdown is essentially due to a reduction in the growth of average earnings, which is more pronounced under both mitigation scenarios than under the reference case.

The large increases in income between 2005 and 2030 occur due to significant increases in both labour and non-labour incomes. The growth in labour income is driven by the increase in the wage index as indicated by MMRF-Green results. The reallocation of workers across sectors following changes in the sectoral composition of employment also contributes to the growth in labour income. Indeed, the sectors expanding the most are found within the service industry which is an industry that tends to provide relatively high wages.

Compared to the other quintiles, the lowest income quintile sees moderate growth, which is somewhat improved in the mitigation scenarios, due to the returned permit revenue. The low growth in income in the bottom decile is due to a large extent to the imposed assumption in MMRF-Green that all benefit payments (making up a large part of the bottom quintile's incomes) increase by the CPI only, which implies zero real growth for benefit recipients. As expected, income growth at the national level is slightly lower under the 450ppm scenario than under the 550ppm scenario due to slower growth in employment and the wage index. However, the lowest quintile has a higher RNI under the mitigation scenarios than under the reference case due to the returned permit revenue, which appears to overcompensate this group for the introduction of the mitigation policies. Indeed, the 450ppm scenario is the most favourable scenario for this quintile due to the larger lump sum transfers. Overall, however, it is clear that households in quintiles 1 and 2 benefit much less from economic growth than the other three quintiles under all scenarios.

The graphs show clearly that between 2005 and 2030 the highest income quintiles experience the largest increases in real incomes. For quintiles 3, 4, and 5 there is a clearly reduced income growth between 2010 and 2015 but then RNI increases in a similar manner as the reference case, although the income levels attained by 2030 remain clearly lower than under the reference case. When all quintiles are taken together, the RNI per adult equivalent is dominated by the effects observed for quintiles 3, 4, and 5.

income per adult equivalent, but the average real net equivalised income is based on all individuals in these 20 per cent of income units.

[22] The actual growth of real net income per person between the two financial years 2003/2004 and 2005/2006 was 8.4 per cent, which translates into an annual growth of 4.1 per cent. On average between 1996/97 and 2007/08, growth per year was 2.9 per cent (ABS, 2008). The increase from 2005 to 2010 in Figure 1 corresponds to an annual increase of 2.3 per cent per equivalent adult and 2.2 per cent per person. It therefore implies a slight slowdown in growth compared to the past decade.

Figure 1 Average real net income per adult equivalent by income quintile (in financial year 2005/2006 dollars)

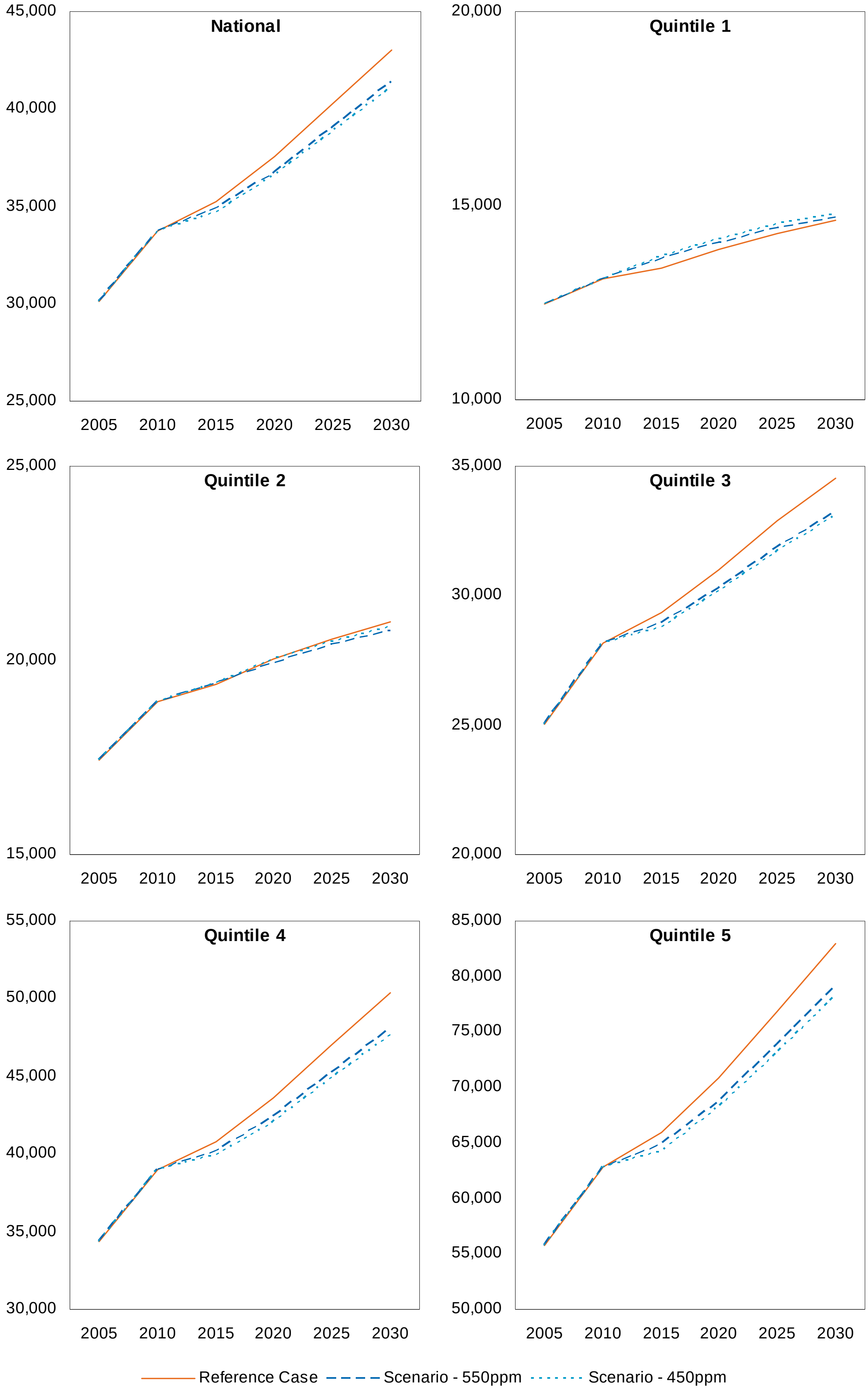


Figure 2 Average real net income per adult equivalent by household type (in financial year 2005/2006 dollars)

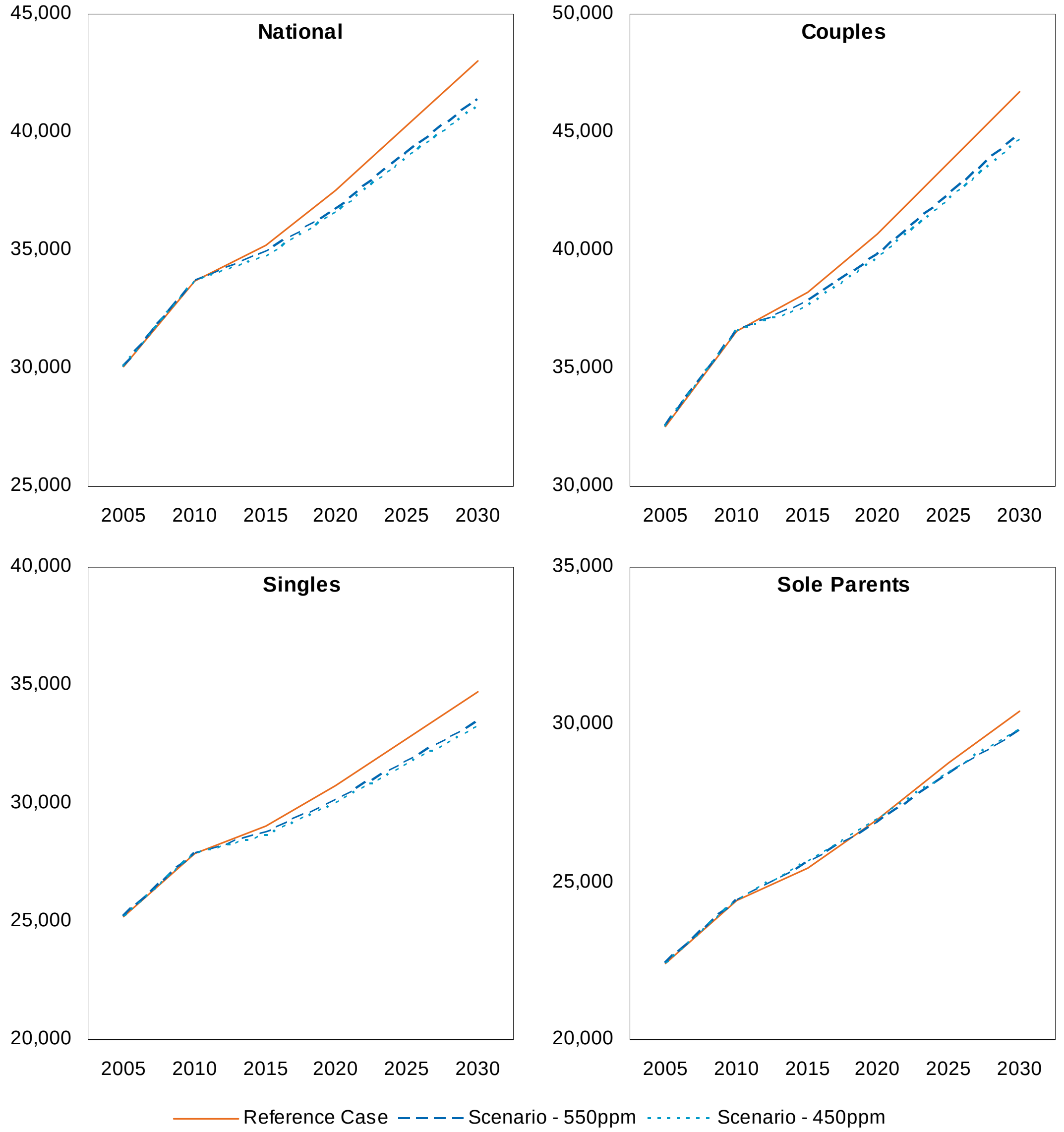


Figure 2 shows that both RNI levels and RNI growth are highest for couple families (this group includes couples with and without children) and lowest for single parents. There is a decrease in the increase of income for singles and couples from 2010 to 2015, although on average the income of all household types still increases in this period. From 2015, real income growth accelerates again, although it remains at a slightly lower rate under the 550ppm and 450ppm scenarios than under the reference case for couples with or without children and singles. As a result, the gap in RNI between the reference case and the two mitigation scenarios increases over time for these two demographic groups. The situation is different for sole parents because their RNI increases more under the mitigation scenarios than under the reference case up to 2015. From 2020 onwards the RNI for sole parents is lower under the mitigation scenarios. Low-income households are overrepresented in the sole parents group, so similar to the lowest quintiles in Figure 1, the sole parent group appears to be better off, at least for a while, under the mitigation policy scenarios than under the reference case.

Figure 3 shows that the changes in incomes over time are accompanied by an increase in income inequality as measured by the Gini coefficient. This is due to the much higher income increases for the higher income quintiles compared to the lower income quintiles. This is mainly due to the assumption made in MMRF-Green regarding the indexation of benefit payments to the CPI rather than the wage index. The increase in CPI is usually much lower than the increase in the wage index over the same time. Currently, all Australian pension payments are indexed with average male weekly earnings.

Comparing the reference case with the two scenarios, the increase in the Australian-wide inequality is smaller under the 450ppm and 550ppm scenarios than under the reference case, and between 2010 and 2015, it is actually slightly decreasing. The mitigation policies appear to reduce the Gini coefficient both overall and within each income quintile, although the reduction is minimal and mainly restricted to quintiles 2 and 3.

Figure 3 shows that there is a reduction in inequality at the national level when comparing the two mitigation scenarios with the reference case. The lump sum transfers taking place under the mitigation scenarios have a dampening impact on the Gini coefficients since they are equally distributed on a per capita basis. In addition, income growth is lower under the two mitigation scenarios so that the divergence between factor income and benefit payments is reduced (should the permit revenues be returned to households in a way that targets low-income households, then inequality might be further reduced).

The graphs in Figure 1 show that the reduction in income growth under the two mitigation scenarios is higher for the higher income quintiles, for which factor income is much more important than benefit payments. This is an interesting result since there is a concern that lower income groups are affected more severely by climate change and by the subsequent policy changes aimed at mitigating the climate change effects, resulting in higher income inequality. However, it seems that other changes over time rather than the mitigation policies are causing an increased inequality and a worse relative income position for the lower income quintiles. Compared to the change in the national Gini over time, the difference between the scenarios and the reference case at each point in time is small. So the effect of climate change mitigation policies (that is the 450 and 550ppm scenarios) on the Gini is limited, compared to other changes predicted to occur over time.

Figure 3 Gini coefficient within income quintiles

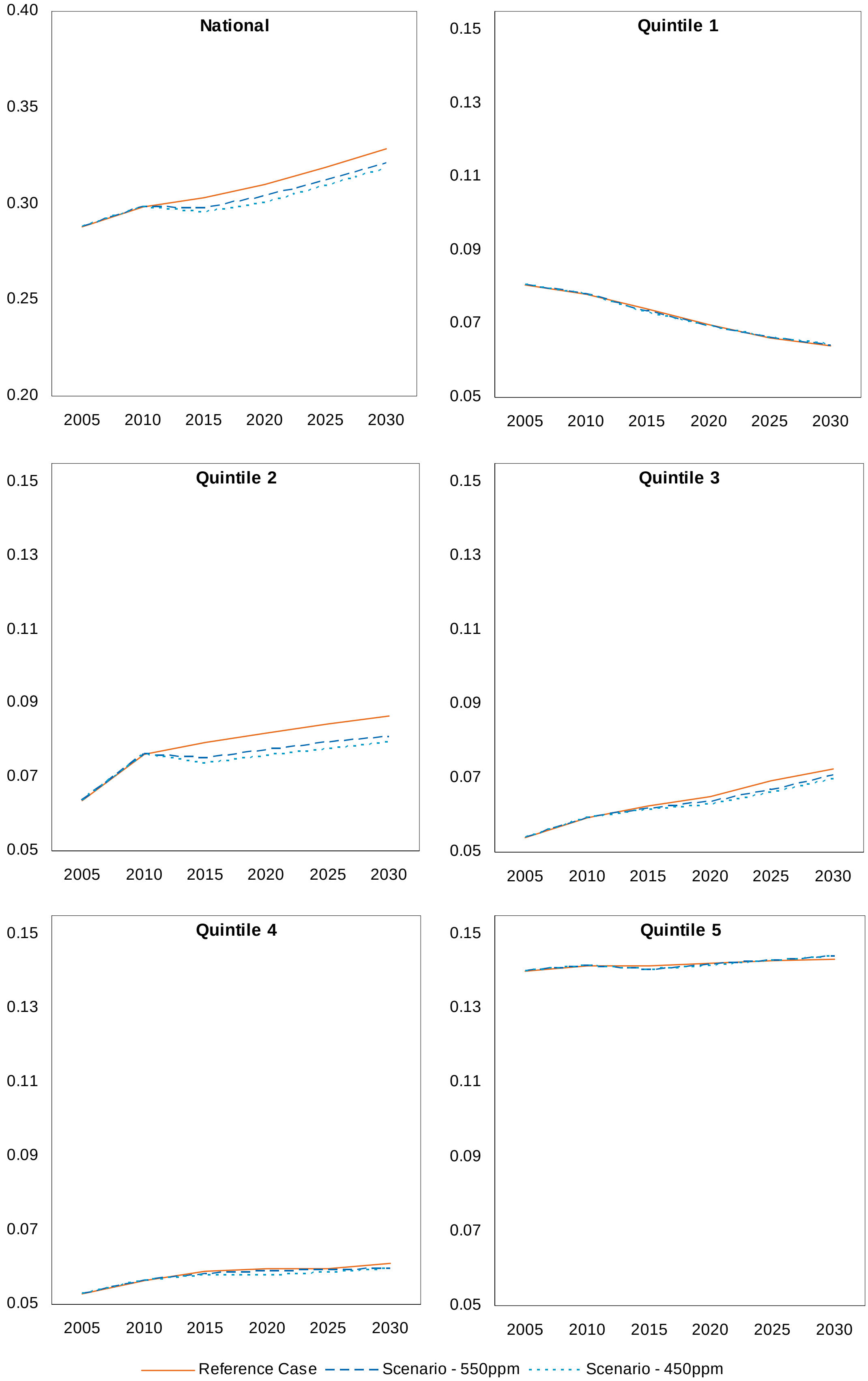
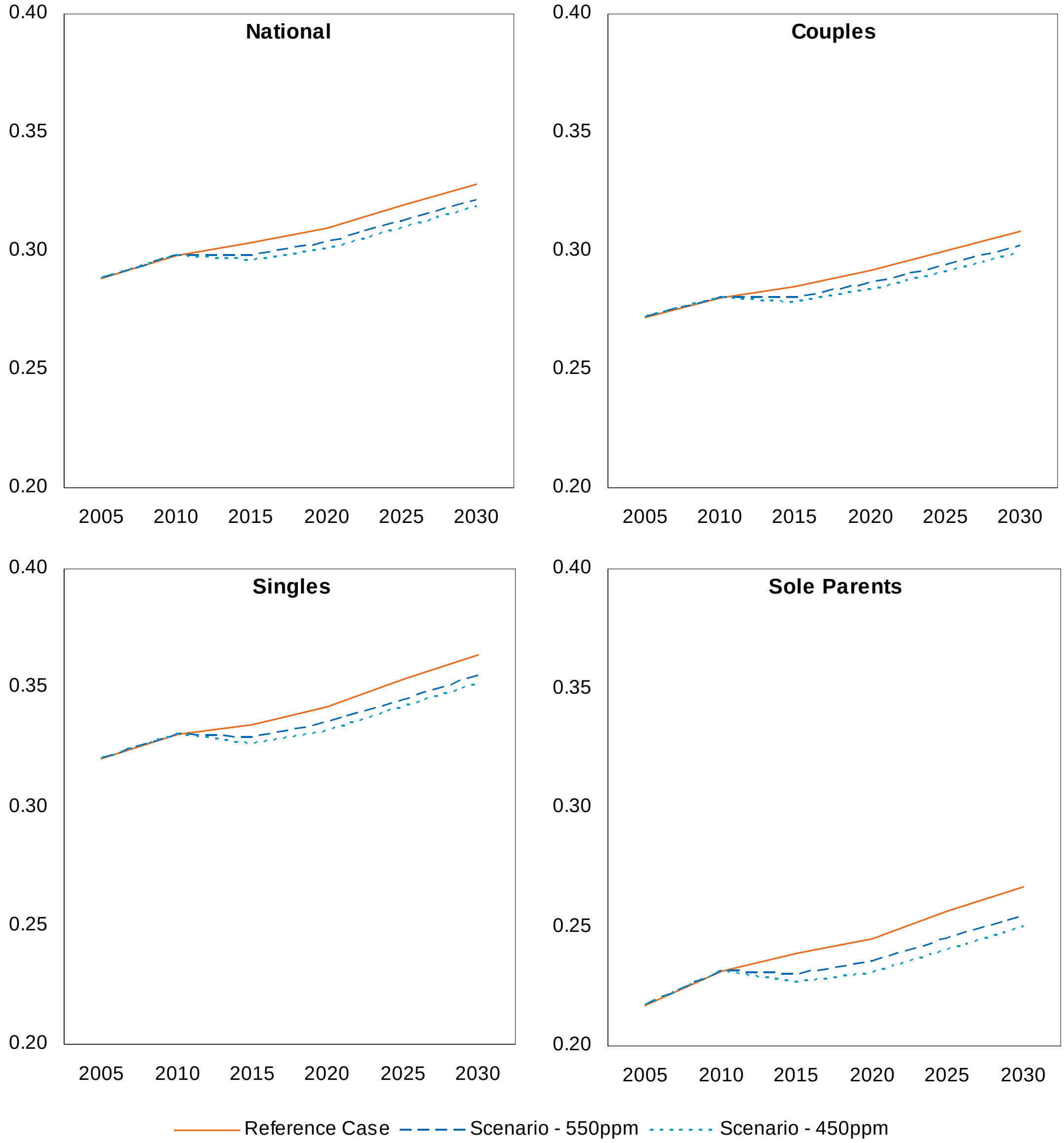


Figure 4 Gini coefficient by household type



Comparing the Gini coefficients by income quintile shows that the highest inequality within a quintile is observed in the top income quintile. This is not surprising due to the wider range of incomes in this quintile compared to the lower quintiles. However, over time the increase in inequality is not as large in this top quintile as in some of the lower quintiles, in particular in quintiles 2 and 3. The Gini coefficient in quintile 1 decreases whereas the Gini increases over time in all the other quintiles. The decrease over time in inequality in the first quintile is due to the increase in the proportion of households in this quintile who are on benefit payments. These payments are fixed amounts depending on household composition and the reason for eligibility only. The households most dependent on benefit payments tend to fall into the first quintile because benefit payments are not increasing over time in real terms. As the share of households dependent on benefit payments increases among quintile 1, inequality falls because benefit payments are more evenly spread across households than other sources of income would be. The substantial lump sum transfers taking place under both mitigation scenarios reinforce this trend and reduce the increase in the Gini coefficient for the other quintiles.

Comparing the Gini by household type shows that single parents have the lowest inequality, which indicates that they form a more homogenous group than singles or couples in terms of RNI. A likely explanation is that a large proportion of their income depends on benefit payments. Possibly for the same reason, single parents display the highest increase in inequality over time. By design, benefit payments increase to a lower extent than labour income, so that working single parents move away from the rest of the distribution over time causing inequality to increase. Again, the lump sum transfers associated with the introduction of the ETS substantially reduce the increase in inequality in these three demographic groups.

5. Conclusion

This paper considers a specific approach of disaggregating output from a dynamic computable general equilibrium (CGE) model into impacts at the household and individual level for the period from 2005 to 2030. The paper draws on previous work by Robilliard *et al.* (2001) which aimed at linking a CGE model and a microsimulation model in a sequential way.

The approach used in this paper relies on altering the sample weights in order to reproduce population projections and the changes in employment as predicted by the CGE model. The transmission of price changes as well as income changes from the CGE to the microsimulation model remains similar to what can be found in the literature. That is, it relies on the transmission of average changes since CGE models only produce changes at the aggregate level. Our novel approach, based on adjusting sample weights, has two advantages. First, it allows the linking of a microsimulation model to a dynamic, and not simply a static, CGE model. Second, it allows the microsimulation model to reproduce the long-term demographic changes predicted by the CGE model to occur over time in the base population.

The main interest of using such an approach is that it allows the computation of the potential distributional effects of the policy change simulated in the CGE model. In this paper, the approach is applied to assess the impacts on household income of two climate-change mitigation policies compared to a reference case without mitigation. The simulations are carried out for the period from 2005 to 2030 in Australia.

Such work always involves a large number of assumptions and therefore the results that are presented should be interpreted with caution. The paper has discussed a range of important assumptions and limitations. Ideally, the sensitivity of results to a range of assumptions should be checked before drawing any strong conclusions. A number of assumptions used in this paper were imposed by the specific CGE results used as input to the microsimulation stage (and in theory, these could be changed to be made more suitable for the distributional analysis). The microsimulation modelling would also benefit from access to aggregate results which would provide more detail on a number of key outcomes, such as for example, wage and employment changes by occupation or skill level.

Despite these caveats, the results from this analysis are of interest and an important first step in setting up this type of analysis. From this analysis it appears further work would be viable and is likely to be productive. Future work could be based on alternative CGE analyses designed to capture the effects of mitigation policy changes (and associated compensation arrangements) on the income and welfare of individual households in an improved way and/or to assess the sensitivity of results to alternative assumptions.

Appendix A: MMRF-Green output

Appendix Table A.1 MMRF-Green output to be used in MITTS

	Changes over time	Changes across scenarios	Changes broken down by	Additional information	MMRF assumptions	Information used by MITTS
Population						
Population (projections from Treasury and ABS 2005, series B)	Yes Exogenous	No	State	In MITTS we also use age and gender, as provided by Treasury	Adopts Treasury projections but only total population by State is used in MMRF	Population projections by age, gender and State from Treasury
Interstate migrations	Yes Combination of exogenous (Treasury) and endogenous changes	No	No breakdown	Changes determined by Treasury + MMRF	Interstate migrations only affect population size (but not population composition)	State populations for all scenarios from MMRF
Labour Market						
Employment levels	Yes in short run No in long run	Yes	State & industry			Changes in employment levels by State and industry + base values
Unemployment levels	Yes	Yes	State			Changes in unemployment levels by State + base values
Wages	Yes Endogenous	Yes	State		Flexible wages	Percentage changes in average real wages by State
Wage differentials by State & industry	No	No	-		Wage differentials are fixed	
Prices						
Price changes	Yes Endogenous	Yes Endogenous	63 commodities State		CPI = numéraire	63 price changes from the 8 regions

Appendix Table A.1 Continued

	Changes over time	Changes across scenarios	Changes broken down by	Additional information	MMRF assumptions	Information used by MITTS
Tax and social security system						Initial tax rates and benefit levels (for comparison purposes)
Income tax rates	No	No	No breakdown, just 1 national average			-
Unemployment benefits	Yes Endogenous	Yes Endogenous	State	Indexed to CPI	Fixed in real terms (aggregate amount follows number of unemployed)	CPI index
Pensions	Yes Endogenous	Yes Endogenous	State	Indexed to CPI	Fixed in real terms (aggregate amount follows population size)	CPI index
Disability grant and other government benefits	Yes Endogenous	Yes Endogenous	State	Indexed to CPI	Fixed in real terms (aggregate amount follows population size)	CPI index
Non-labour factor income						
Non-labour factor income	Yes Endogenous	Yes Endogenous	State	Includes profit, dividends, income from own business, income from agricultural land (latter is small), rents and imputed rents. See National accounts.		Average changes in household real capital returns by State
Household expenditures						Initial budget shares of 63 commodities by State and concordance tables
Consumption patterns	Yes Endogenous	Yes Endogenous	State and 63 commodities	ABS ANZSIC classification	63 commodities include 3 energy-related commodities CPI = numéraire	Changes in 63 budget shares by State

Note: Endogenous means that changes in the corresponding variables are determined by MMRF-Green. Exogenous means that changes (if any) are exogenous to MMRF-Green.

Appendix B: The Reweighting Procedure

The calibration approach used in this paper produces new weights which achieve specified population totals for selected variables, subject to the constraint that there are minimal adjustments to the original weights. The chi-squared distance function is used as the measure to minimise adjustments to the original weights. The chi-squared type of distance measure gives the aggregate distance by[23]:

$$D = \frac{1}{2}\sum_{k=1}^{K}\frac{\left(w_k - s_k\right)^2}{s_k} \tag{B.1}$$

A modification is applied to restrict the range of deviation in the revised weights (w_k) from the original weights (s_k). A detailed technical description of this approach can be found in Cai *et al.* (2006).

Table B.1 summarises by how much each sample weight changes due to the reweighting procedure through reporting the size of the factor of change at each decile point of these changes. It indicates how the sample weights are affected by the reweighting procedure in the reference case. Results for the other scenarios are not reported given that they are very similar. The main reason for this similarity is that population projections are the same across scenarios and that differences in employment projections across scenarios are limited.

Table B.1 Ratio of new weights to original sample weights: Reference case

	2005	2010	2015	2020	2025	2030
Decile 1	0.64	0.63	0.63	0.59	0.53	0.47
Decile 2	0.77	0.79	0.82	0.80	0.77	0.71
Decile 3	0.87	0.90	0.94	0.95	0.93	0.91
Decile 4	0.94	0.99	1.05	1.09	1.08	1.07
Decile 5	1.02	1.08	1.16	1.22	1.26	1.28
Decile 6	1.10	1.18	1.27	1.38	1.42	1.50
Decile 7	1.18	1.30	1.44	1.55	1.69	1.77
Decile 8	1.30	1.45	1.61	1.77	1.95	2.15
Decile 9	1.51	1.76	1.94	2.15	2.40	2.71

Note: This table should be read as follows: for 10 per cent of the records, the ratio of the new weight for 2005 (after reweighting) to the original sample weight is smaller than 0.64. For another 10 per cent of the records it is higher than 1.51.

[23] Details of the relevant population totals are presented in Appendix D of Buddelmeyer *et al.* (2008).

Appendix C: Assumptions and Limitations

This appendix provides a concise overview of a range of important assumptions that are relevant to the modelling in this paper. Due to the ‘top-down’ approach, the microsimulation modelling inherits all the assumptions underlying the CGE model. Therefore the most relevant MMRF-Green assumptions are listed in C.1 before the assumptions underlying the microsimulation analysis in C.2. Finally, the main limitations of the modelling approach are listed in C.3.

C.1 MMRF-Green Assumptions

- Treasury’s projections form the basis of the population projections underlying MMRF-Green.
- Treasury projections are altered by interstate migration as predicted by MMRF-Green.
- Employment levels by industry and region are determined by the model.
- The long-run rate of unemployment is assumed to be fixed.
- Changes in average wages differ by region but not by industry (nor occupation).
- Base values of wages differ by region and industry (not by occupation).
- 63 different commodities are distinguished whose relative prices are endogenous and change over time.
- Relative price changes differ by region and policy run.
- Each of the eight regions has one single representative household with its own consumption function.
- Adjustments in the 63 budget shares following price changes are determined at the regional level.
- The same exogenous single income tax rate is applied to all representative households.
- It is assumed that climate change itself will not have a direct economic impact before 2030.
- Benefits from the mitigation policies resulting from a reduced adverse effect on climate will only become evident after 2030.

C.2 MITTS Assumptions/Approximations

C.2.1 The population in MITTS

- The 2003/2004 Survey of Income and Housing Cost (SIHC), collected by the Australian Bureau of Statistics (2007) and updated to the 2005/2006 financial year, is the base year file used in MITTS.

- Treasury population projections are altered by MMRF-Green, but MMRF-Green does not provide information about the new age and gender structure of regional populations. A two-step reweighting approach ensures that MITTS is consistent with MMRF-Green and that the deviations between MITTS and Treasury projections are minimal.
- MITTS is reweighted separately for every year for which a simulation is run (including base year), benchmarking the MITTS input data against MMRF-Green output to reproduce the required employment and population changes over time.
- The industry classification is more aggregated in MITTS (13 industry groups) than in MMRF-Green (55 industry groups) thus MMRF-Green industries are mapped into MITTS industries.

C.2.2 Income and wages

- All results are expressed in 2005/2006 or base year prices.
- Financial information in 2003/2004 is increased to reflect January 2010, 2015, 2020, 2025 and 2030 values. Non-labour income in MITTS is updated using MMRF-Green changes for non-labour income.
- Wage rates are updated using the average male and female wage indices until 2005, while MMRF-Green regional wage indices are used in subsequent years.
- MMRF-Green generates average changes in wages and non-labour factor income only by region. In MITTS, the average change corresponding to the relevant region of residence is applied to each household.

C.2.3 Income tax and social security

- Since MMRF-Green is based on the 2005/2006 financial year, the tax and social security system of January 2006 is used in MITTS.
- All major social security payments and income taxes are included in MITTS.
- The information in the SIHC is used to calculate eligibility for the different social security payments, not accounting for asset tests or residency requirements
- Only income changes in real terms are used so that other eligibility criteria for benefits do not have to be updated to account for inflation.
- A 100 per cent take-up of benefits is assumed.
- Income tax thresholds are indexed to real wages in order to hold the national average tax rate constant, in accordance with MMRF-Green assumptions.

- Following MMRF assumptions, all individual-benefit payments are indexed to the Consumer Price Index (CPI) in order to be held constant in real terms.

C.2.4 Income quintiles

- Income quintiles are determined at the income unit level and are based on the ranking of income units according to real disposable income per adult equivalent.
- Equivalising of incomes is achieved using the Whiteford equivalence scale.
- New income quintiles are computed for each year of the analysis since it cannot be assumed that income units belonging to a particular quintile will still belong to the same quintile five years later.
- Income quintiles differ across scenarios because changes in incomes and employment are different across scenarios.

C.2.5 Consumption behaviour

- Cumulative price changes by commodity from MMRF-Green are combined with the previous period's budget shares to compute real incomes adjusted for household-specific consumption patterns. Using the current budget shares is not appropriate because it would imply a 'double counting' of the price effects (via their effects on consumption patterns, on top of the price effects).
- MITTS does not include a model explaining consumption. Changes in consumption patterns as predicted by MMRF-Green are required as input, and this represents all behavioural responses.
- In MMRF-Green, changes in consumption patterns are only available at the regional level and therefore the same budget share changes (in percentage points) are applied to all households' budget shares within the same region. If these adjustments result in negative budget shares these are replaced by zero. All budget shares are evenly scaled to add up to 100 per cent following adjustment.
- The 600+ expenditure items in the Household Expenditure Survey (HES) are mapped to the 63 commodities used in MMRF-Green.

C.3 Limitations

- Changes in wages are available only at a highly aggregated level in MMRF-Green (changes in wages only differ by region).
- The MMRF-Green model does not distinguish between skilled and unskilled workers, which is a limitation with regard to wage and employment developments.

- Similarly there is no distinction in consumption responses to price changes between low and high income households.

Appendix D: Tables corresponding to Figures 1 to 4

Table D.1 Average real net income per adult equivalent by income quintile

		2005	2010	2015	2020	2025	2030
	Reference Case	12,452	13,122	13,400	13,872	14,267	14,623
Quintile 1	Scenario - 550ppm	12,452	13,122	13,646	14,028	14,405	14,698
	Scenario - 450ppm	12,452	13,122	13,711	14,159	14,530	14,806
	Reference Case	17,434	18,940	19,392	20,038	20,551	21,008
Quintile 2	Scenario - 550ppm	17,434	18,940	19,428	19,946	20,423	20,766
	Scenario - 450ppm	17,434	18,940	19,420	20,033	20,483	20,839
	Reference Case	25,051	28,178	29,327	30,982	32,870	34,532
Quintile 3	Scenario - 550ppm	25,051	28,178	28,957	30,266	31,847	33,270
	Scenario - 450ppm	25,051	28,178	28,805	30,180	31,708	33,110
	Reference Case	34,397	38,949	40,772	43,617	47,055	50,343
Quintile 4	Scenario - 550ppm	34,397	38,949	40,192	42,379	45,222	48,055
	Scenario - 450ppm	34,397	38,949	39,901	42,098	44,865	47,602
	Reference Case	55,734	62,855	65,991	70,817	76,879	82,986
Quintile 5	Scenario - 550ppm	55,734	62,855	64,893	68,747	73,893	79,129
	Scenario - 450ppm	55,734	62,855	64,313	68,174	73,191	78,307
	Reference Case	30,091	33,725	35,223	37,526	40,290	43,010
Total	Scenario - 550ppm	30,091	33,725	34,908	36,739	39,082	41,390
	Scenario - 450ppm	30,091	33,725	34,716	36,601	38,885	41,123

Table D.2 Average real net income per adult equivalent by household type

		2005	2010	2015	2020	2025	2030
	Reference Case	32,556	36,597	38,186	40,675	43,710	46,746
Couples	Scenario - 550ppm	32,556	36,597	37,818	39,786	42,355	44,930
	Scenario - 450ppm	32,556	36,597	37,595	39,625	42,130	44,633
	Reference Case	25,236	27,904	29,056	30,767	32,765	34,696
Singles	Scenario - 550ppm	25,236	27,904	28,785	30,122	31,797	33,429
	Scenario - 450ppm	25,236	27,904	28,629	29,985	31,610	33,187
	Reference Case	22,429	24,439	25,436	26,986	28,759	30,404
Sole Parents	Scenario - 550ppm	22,429	24,439	25,612	26,885	28,420	29,835
	Scenario - 450ppm	22,429	24,439	25,653	26,989	28,489	29,838
	Reference Case	30,091	33,725	35,223	37,526	40,290	43,010
Total	Scenario - 550ppm	30,091	33,725	34,908	36,739	39,082	41,390
	Scenario - 450ppm	30,091	33,725	34,716	36,601	38,885	41,123

Table D.3 Gini coefficient within income quintiles

		2005	2010	2015	2020	2025	2030
	Reference Case	0.081	0.078	0.074	0.070	0.066	0.064
Quintile 1	Scenario - 550ppm	0.081	0.078	0.073	0.069	0.066	0.064
	Scenario - 450ppm	0.081	0.078	0.073	0.069	0.066	0.064
	Reference Case	0.064	0.076	0.080	0.082	0.084	0.087
Quintile 2	Scenario - 550ppm	0.064	0.076	0.075	0.077	0.079	0.081
	Scenario - 450ppm	0.064	0.076	0.074	0.076	0.078	0.079
	Reference Case	0.054	0.059	0.062	0.065	0.069	0.073
Quintile 3	Scenario - 550ppm	0.054	0.059	0.062	0.063	0.067	0.071
	Scenario - 450ppm	0.054	0.059	0.061	0.063	0.066	0.070
	Reference Case	0.053	0.057	0.059	0.060	0.060	0.061
Quintile 4	Scenario - 550ppm	0.053	0.057	0.058	0.059	0.059	0.060
	Scenario - 450ppm	0.053	0.057	0.058	0.058	0.059	0.059
	Reference Case	0.140	0.141	0.141	0.142	0.143	0.143
Quintile 5	Scenario - 550ppm	0.140	0.141	0.141	0.142	0.143	0.144
	Scenario - 450ppm	0.140	0.141	0.140	0.141	0.143	0.144
	Reference Case	0.288	0.298	0.303	0.310	0.319	0.328
Total	Scenario - 550ppm	0.288	0.298	0.298	0.304	0.312	0.321
	Scenario - 450ppm	0.288	0.298	0.296	0.301	0.309	0.318

Table D.4 Gini coefficient by household type

		2005	2010	2015	2020	2025	2030
	Reference Case	0.272	0.280	0.285	0.291	0.300	0.308
Couples	Scenario - 550ppm	0.272	0.280	0.280	0.286	0.294	0.302
	Scenario - 450ppm	0.272	0.280	0.278	0.283	0.291	0.300
	Reference Case	0.320	0.330	0.335	0.342	0.353	0.364
Singles	Scenario - 550ppm	0.320	0.330	0.329	0.335	0.345	0.355
	Scenario - 450ppm	0.320	0.330	0.326	0.332	0.342	0.352
	Reference Case	0.217	0.231	0.238	0.245	0.257	0.267
Sole Parents	Scenario - 550ppm	0.217	0.231	0.230	0.235	0.245	0.254
	Scenario - 450ppm	0.217	0.231	0.226	0.231	0.240	0.250
	Reference Case	0.288	0.298	0.303	0.310	0.319	0.328
Total	Scenario - 550ppm	0.288	0.298	0.298	0.304	0.312	0.321
	Scenario - 450ppm	0.288	0.298	0.296	0.301	0.309	0.318

References

Adams, P.D., Horridge, M. and Wittwer, G. (2002), 'MMRF-GREEN: A Dynamic Multi-Regional Applied General Equilibrium Model of the Australian Economy, Based on the MMR and MONASH Models', Draft documentation prepared for the Regional GE Modelling Course, Centre of Policy Studies, Monash University.

Adams, P.D., Horridge, M. and Wittwer, G. (2007), 'MMRF: A Dynamic Multi-Regional Applied General Equilibrium Model of the Australian Economy', Draft documentation prepared for the Regional GE Modelling Course 16-21 July 2007, Centre of Policy Studies, Monash University.

Australian Bureau of Statistics (ABS) (2005), Population Projection Australia 2004–2101, ABS Cat no. 3222.0.

ABS (2007), Household Expenditure Survey and Survey of Income and Housing - Confidentialised Unit Record Files, Technical Manual, Cat. No. 6540.0.00.001, Canberra.

ABS (2008) *Measures of Australia's Progress: Summary Indicators, 2008* (Edition 2), Catalogue no. 1383.0.55.001, Canberra.

Binh, T. N. and Whiteford, P. (1990), 'Household equivalence scales: new Australian estimates from the 1984 Household Expenditure Survey', *Economic Record*, 66, 221-234.

Buddelmeyer, H., Hérault, N., Kalb, G. and van Zijll de Jong, M. (2008), Disaggregation of CGE results into household level results through micro-macro linkage: Analysing climate change mitigation policies from 2005 to 2030, Melbourne Institute Report No. 9, University of Melbourne.

Cai, L., Creedy, J. and Kalb, G. (2006), 'Accounting for Population Ageing in Tax Microsimulation Modelling by Survey Reweighting', *Australian Economic Papers*, 45(1), 18-37.

Commonwealth of Australia (2008), *Garnaut Climate Change Review*, draft report, June 2008.

Commonwealth Treasury (2008), Climate change mitigation policy modelling; Summary of assumptions and data sources, October 2008, available on: http://www.treasurer.gov.au/Ministers/wms/Content/pressreleases/2008/attachments/108/Treasury climate change mitigation policy modelling assumptions.pdf

Creedy, J., Duncan, A.S., Harris, M., and Scutella, R. (2002), *Microsimulation Modelling of Taxation and The Labour Market: The Melbourne Institute Tax and Transfer Simulator,* Cheltenham: Edward Elgar.

Deville, J.-F. and Särndal, C.-E. (1992), 'Calibration estimators in survey sampling', *Journal of the American Statistical Association*, 87, 376-382.

Ferreira, J. and Horridge, M. (2006), The Doha Round, Poverty and Regional Inequality in Brazil, Chapter 7 in Thomas W. Hertel and L. Alan Winters (eds), *Putting Development Back into the Doha Agenda: Poverty Impacts of a WTO Agreement*, Palgrave Macmillan and the World Bank, Washington, D.C.

Garnaut, R. (2008), *The Garnaut Climate Change Review: Final Report*, Commonwealth of Australia, Cambridge University Press: Melbourne.

Hérault, N. (2009), Sequential Linking of Computable General Equilibrium and Microsimulation Models, Melbourne Institute working paper no. 2/2009, University of Melbourne.

Robilliard, A.-S., Bourguignon, F. and Robinson, S. (2001), Crisis and Income Distribution: A Micro-Macro Model for Indonesia, Paper presented at the OECD Development Center Conference, 9-10 December 2002, Paris, France.