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Abstract

This paper presents a method of computing welfare changes (compensating and equivalent variations) arising from a tax or social security policy change, in the context of behavioural microsimulation modelling where individuals can choose between a limited number of discrete hours of work. The method allows fully for the nonlinearity of the budget constraint facing each individual, the probabilistic nature of the labour supply model and the presence of unobserved heterogeneity in the estimation of preference functions. An advantage of welfare measures, compared with changes in net incomes, is that they take into account the value of leisure and home production. The method is applied to hypothetical income tax policy changes in Australia and comparisons are made at the individual and the aggregate level. At the aggregate level a social welfare function is specified in terms of money metric utility. It is shown that policy evaluations based on welfare changes can be substantially different from those using only individuals' net income changes.

1 Introduction

The aim of this paper is to examine the use of welfare measures in the special context of labour supply models, where individuals typically face highly nonlinear budget constraints and where the appropriate price, the net wage rate, is endogenous as well as labour supply itself. Few of the studies which estimate utility or labour supply functions actually produce individual measures of the welfare effects of tax reforms. Recent developments in behavioural tax microsimulation modelling and its use in policy analyses make the computation of such measures possible and provide a strong motivation for developing convenient methods of obtaining accurate welfare measures. The advantage of welfare measures over income-based measures in behavioural microsimulation is that they can take into account the value to the household of leisure and home production time. This is in addition to the changes in individuals' budget constraints resulting from a policy change which induces labour supply responses.

Where welfare changes have been produced in the labour supply context, the approach has been to adopt a minor modification of the standard expressions used to obtain welfare changes.[1] However, Creedy and Kalb (2005b) showed that this standard approach does not allow sufficiently for the usual nonlinearity of the budget constraint facing an individual. A method of computing the welfare change, allowing for the full relevant detail of budget constraints, was suggested and illustrated.[2] The method can be applied to a wide range of utility specifications, independent of whether the expenditure function can be written down explicitly.

The modification to the welfare measure computation required when only a discrete number of hours levels are allowed is presented in Section 2. Discrete hours models are used in applied work because of the substantial econometric advantages resulting from directly estimating the parameters of specified direct utility functions. This avoids problems concerning the endogeneity of the net wage in continuous hours models and the need to solve the first-order conditions for utility maximisation, or even to know the full budget constraint facing each individual. As no explicit labour supply function is needed, a wide range of direct

[1] See for example Hausman (1981, p. 672; 1985, pp. 243-245), Blomquist (1983, pp. 187-190), Blundell, Preston and Walker (1994, pp. 4-8), and Creedy (2000, 2001). In the context of commodity demands, including situations in which there may be quantity constraints, a general approach was suggested by Neary and Roberts (1980), exploiting the Hicksian concept of virtual price; see also Latham (1980) or Johansson (1987). In these cases it is usual to define a modified expenditure function conditional on the rationed levels of consumption.

[2] In allowing for the nonlinearity it differs from Apps and Rees (1999) and in its simple and wide applicability it differs from Preston and Walker (1999).

utility functions can be used.[3] In addition, it is argued that in practice individuals have limited choices over the extent to which they can vary their hours. Discrete hours labour supply models therefore predominate in behavioural microsimulation modelling.

The implementation of the approach is described in Section 3, outlining the required assumptions. The discussion concentrates on the compensating variation, since no different principles are involved in obtaining the equivalent variation. However, both measures of welfare change are reported when examining applications. The discussion of the method of measuring welfare changes assumes that an individual's utility function is deterministic and is known precisely. In practice, the discrete hours approach is probabilistic, in that a random term is added to the deterministic component of the utility function, giving rise to a probability distribution over the hours alternatives. Furthermore, estimation uses data for members of a particular demographic group in which some unobserved individual heterogeneity in preferences remains. The use of the relevant utility function's parameter estimates to obtain a household's value for welfare changes in tax microsimulation modelling is discussed in Section 3, using the example of a quadratic utility function. The approach is used to evaluate two simple policy reforms involving changes in income taxation rates. The microsimulation model, MITTS (the Melbourne Institute Tax and Transfer Simulator), is used to generate results. Brief details of the model are given in the Appendix. The implications of the policy changes are examined in Section 4 and comparisons are made between measures of welfare change and net income changes. Brief conclusions are in Section 5.

2. Measuring Welfare Changes

This section shows how welfare measures can be obtained in labour supply models. The basic framework with continuous hours is described in subsection 2.1, which presents an expression for welfare changes and shows how the standard approach gives rise to problems when applied in situations with nonlinear budget constraints. Subsection 2.2 presents the method of computing welfare changes in the discrete hours framework.

2.1 The Basic Framework

Let h denote the number of hours devoted to labour supply, which may be varied

[3] For a general discussion of alternative approaches to labour supply modelling, see Creedy and Duncan (2002). In the continuous case, even if estimation is based on an explicit labour supply function (expressed in terms of μ and w), a welfare measure can only be obtained by integrating from the labour supply to the expenditure function. This integration may need to be carried out numerically.

continuously, and let c denote net income. In a static framework, with the price index normalised to unity, net income and consumption are equal. The direct utility function is written as $U(c, h)$. Leisure is $T - h$ where T is the total number of hours available for work and leisure. The tax and transfer system is characterised by a piecewise-linear budget constraint.

Any optimal position, combining c and h, can be regarded as being generated by a virtual linear constraint of the form:

$$c = wh + \mu \qquad (1)$$

For tangency solutions, w and μ represent the net wage rate along the relevant segment of the piecewise linear constraint and virtual income respectively. The latter is distinct from actual non-wage income and is the non-wage income (the intercept of the extended segment on the consumption axis) that would apply if the extended segment were the full constraint. With a corner solution, the virtual wage is the slope of the indifference curve at the kink and virtual income is the value generated by a linear constraint having a net wage equal to the virtual wage. An important characteristic of the optimal position is that the net wage and virtual income, as well as the hours worked, are endogenous.

The evaluation of welfare changes requires an expression for the expenditure function, giving the minimum expenditure needed to reach a specified indifference curve at a given net wage rate. This can be written in terms of virtual income, using $\mu(w, U)$.[4] Suppose there is a change in taxes and transfers from system 0 to system 1. Values in each system are indicated by 0 and 1 subscripts. The compensating variation is the minimum amount of money necessary to return the individual to the same utility level as in system 0 after the change to system 1. A tax rate change has both price (of leisure) and (virtual) income effects. The price effect is $\mu(w_1, U_0) - \mu_0$ while the income effect is $\mu_0 - \mu_1$, so that the standard expression for the compensating variation is:

$$CV = \mu(w_1, U_0) - \mu_1 \qquad (2)$$

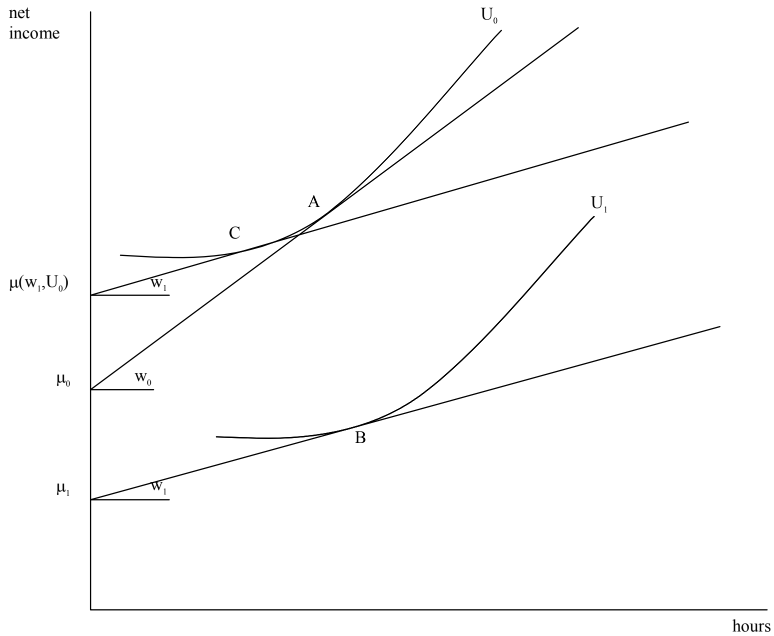
where w_i is either the virtual or actual net wage rate at the optimum position under policy i, U_i is the maximum utility that can be reached under tax system i, and $\mu_i = \mu(w_i, U_i)$. These welfare changes are defined so that they are positive for a loss.[5] This is illustrated in Figure 1,

[4] Virtual income, $\mu(w, U)$ is obtained by first obtaining the indirect utility function. Substitute $c = wh + \mu$ into $U(c, h)$, and substitute the solution for optimal h, from $\left.\frac{dc}{dh}\right|_U = w$ and $c = wh + \mu$ into U. Then invert the indirect utility function by solving U for μ. Welfare changes can also be expressed in terms of full income, M, which is equal to $\mu + wT$.

[5] The equivalent variation is the maximum amount that can be taken from an individual in order to keep utility constant at the new level; that is after the policy change, if the tax change were reversed. It is equal to the

where a tax change involves a movement from point A to point B.

Figure 1 Compensating variation under a linear budget constraint



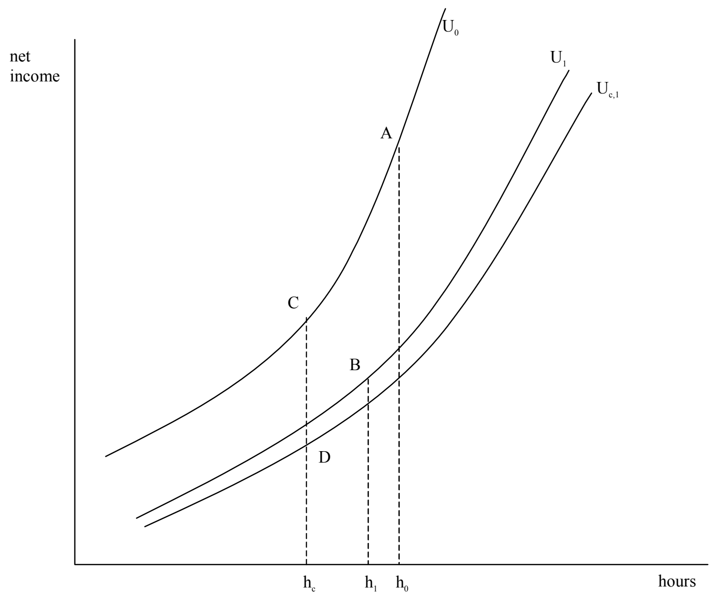
The payment of the compensating variation of $\mu(w_1, U_0) - \mu_1$ allows the individual to reach indifference curve U_0 at point C, while in receipt of net wage w_1 and working fewer hours than at B. This approach implicitly assumes that the virtual budget line in Figure 1, given by the tangent to U_1 at point B, with associated virtual income of μ_1, does in fact apply over the relevant range. That is, the individual can move to the left of B (and therefore increase consumption of leisure) along the linear budget line until the hours worked correspond to those at point C. The addition of the compensated variation to net income allows consumption to increase so that point C can be reached.

Creedy and Kalb (2005b) showed that nonlinearity of budget constraints can imply that the compensating variation, as defined above, is insufficient to restore the individual to U_0. In addition to nonlinearity, the budget constraint may be convex. A convex range occurs if the marginal tax rate falls as hours of work increase. This may happen, for example, when entitlement to a means-tested benefit is exhausted. This case is illustrated in Figure 2 where again a movement takes place from point A to point B. It is possible, even if B were a tangency solution, to have a level of hours, say h_c at point D, where the net income is associated with an indifference curve, say $U_{c,1}$, that is lower than indifference curve U_1 but the

negative of the corresponding compensating variation for a change from tax system 1 to system 0, and is therefore $EV = \mu_0 - \mu(w_0, U_1)$.

increase in net income required to bring utility up to U_0 is a minimum. This is shown in Figure 2 by the length DC.[6] Allowing for discrete hours choices only, the individual's ability to return to U_0 after a policy change is further restricted. The next subsection discusses the computation of welfare measures in a discrete choice framework.

Figure 2 Compensating variation: nonconvex and nonlinear budget constraint



2.2 The Discrete Choice Framework

Starting from a discrete hours model in which individuals are restricted to a limited number of hours levels, $h_1,\ldots,h_H$, the utility function and net incomes at each of the specified hours points are known. Evaluation of the optimal number of hours is therefore easily carried out by calculating utilities at a relatively small number of points, each of which is treated as a corner solution.[7]

It is useful to introduce a new notation system, given the use of $h_1,\ldots,h_H$ to refer to fixed discrete hours levels and the need to consider more than two indifference curves. In addition to the subscript denoting the tax system, each indifference curve is given a superscript which refers to the hours level; that is U_j^k is the utility obtained from combination of the discrete hours level h_k and the associated consumption determined by tax and transfer

[6] The same kind of argument can be applied to the equivalent variation, where it is required to maximise the change in income necessary to reach U_1 from the budget constraint under tax system 0.

[7] This contrasts with the continuous hours case where an efficient search algorithm, such as the one described in Creedy and Duncan (2002), may be adopted.

system j. A similar convention is used when referring to virtual incomes and virtual wages. A superscript indicates the hours index which defines the utility level, while a second subscript refers to the discrete hours level to which the virtual values relate. Hence the virtual wage $w_{0,j}^{k}$ is the slope of indifference curve U_0^k at the discrete hours point h_j. Similarly, $\mu_{0,j}^{k}$ is the corresponding virtual income, the intercept on the net income axis of the tangent to the indifference curve U_0^k at the discrete hours level h_j.

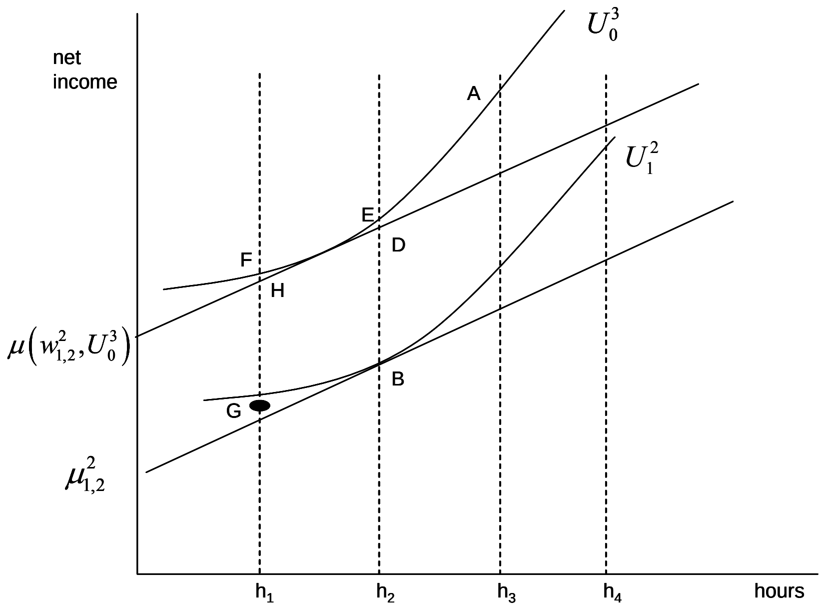
Consider Figure 3, where it is assumed that there are just four discrete hours levels available. The original optimal position in Figure 3 is at point A on indifference curve U_0^3, corresponding to h_3 hours of work. A tax reform causes the optimal position to shift to point B on indifference curve U_1^2, involving h_2 hours of work. Hence the virtual linear budget constraints associated with A and B are defined by the pairs ($\mu_{0,3}^{3}, w_{0,3}^{3}$) and ($\mu_{1,2}^{2}, w_{1,2}^{2}$) respectively.[8] Given the limited hours choices available, calculation of the compensating variation using the standard approach understates the true amount needed to restore the individual to U_0^3. The standard compensating variation is the difference between the net incomes at points E and B, but it is not clear that this is the minimum compensation needed. The possibility must be considered that the individual could work $h_i \neq h_2$ hours and reach indifference curve U_0^3 with a smaller increase to net income than the distance BE.

Using the notation described above, $w_{0,2}^{3}$ denotes the virtual wage corresponding to hours level h_2 at point E on U_0^3, and $\mu_{0,2}^{3}$ represents the associated virtual income.[9] To determine the compensating variation, the distance between the current budget constraint and the net income required to reach the original utility level U_0^3 must be determined at all possible labour supply points. For example, if net income at h_1 in system 1 is at point G (which is above the virtual budget constraint associated with B), it is possible that the distance between G and F is smaller than that between B and E. Even if G were slightly below the virtual budget line through B, it is possible for the compensating variation to be lower than if hours were fixed at h_2, depending on the distance FH compared with ED.

[8] For each discrete hours point, h_j, c_j^0 and c_j^1 can be determined, after which $U\left(c_j^0, h_j\right)$ can be calculated. Then $w_{0,i}^{i}$ is the virtual wage in the optimal point U_0^i and $\mu_{0,i}^{i} = c_i^0 - w_{0,i}^{i} h_i$.

[9] Determine net income $c_{0,2}^{3}$ necessary to reach U_0^3 in h_2 by solving for c in $U\left(c, h_2\right) =$ U_0^3 and then use $\mu_{0,2}^{3} = c_{0,2}^{3} - w_{0,2}^{3} h_2$.

Figure 3 Compensating variation in a discrete choice labour supply context



Point G is the combination of net income on the actual budget constraint under the post-reform tax system and the hours level h_1, so the indifference curve through this point is labelled U_1^1 . If the individual is at G, the compensation required to reach U_0^3 is the length GF and is given by:

$$CV = \left\{\mu_{0,1}^3 + w_{0,1}^3 h_1\right\} - \left\{\mu_{1,1}^1 + w_{1,1}^1 h_1\right\} \tag{3}$$

or equivalently:

$$CV = \left\{\mu_{0,1}^3 - \mu_{1,1}^1\right\} + \left(w_{0,1}^3 - w_{1,1}^1\right) h_1 \tag{4}$$

The appropriate compensation is the minimum of this type of difference, over all discrete hours points. The search for the appropriate hours level, h_c, which produces a minimum compensation is therefore simpler in the discrete hours context, where all possible hours levels are specified *a priori*, compared with the continuous hours framework, where an alternative tangency may apply.

The procedure outlined above requires only the calculation of the net income corresponding to a specified hours level and indifference curve.[10] That is, it is necessary to compute net income, c, corresponding to a specified hours level, h, along an indifference curve with known utility level U, where U is computed from a known different combination

[10] If a utility function is used for which the labour supply and expenditure functions cannot be derived explicitly, it is not possible to obtain an analytical expression for the virtual income $\mu\left(w_{1,2}^2, U_0^3\right)$, shown in Figure 3. However, this does not matter as it is not actually required in the discrete hours context.

of consumption and hours. The minimum difference between this net income and the net income on the post-reform budget constraint is obtained by comparing all discrete labour supply points.

3 Implementation of the Welfare Measure

This section examines some practical aspects of the implementation of the above procedure in the context of behavioural microsimulation modelling. An important characteristic of the discrete hours approach is that it is associated with a probability distribution of hours worked in each tax structure for each individual, rather than a single deterministic hours level. It is therefore necessary to compute an expected value of the welfare change for each individual, and this is discussed in subsection 3.1. The MITTS model's labour responses are based on quadratic direct utility functions, estimated separately for each demographic group. Specific issues in relation to this utility function are discussed in subsection 3.2. The problems arising when some of the hours levels for some individuals are associated with ranges of the utility function where utility actually falls, as consumption (net income) increases, are examined. Finally, subsection 3.3 considers the overall evaluation of a policy change using explicit value judgements.

3.1 Computation of Expected Welfare Changes

In describing the method used to deal with piecewise linear budget constraints, it was assumed that the individual's utility function is known precisely. However, in the discrete hours approach to specification and estimation, direct utility functions are assumed to consist of a deterministic and a random component. The latter implies that each individual has a probability distribution over the available hours levels, rather than a single deterministic labour supply. Furthermore, estimation is carried out for members of a particular demographic group, for whom some unobserved heterogeneity in preferences remains. This is despite the fact that parameters can depend on a wide range of observed characteristics of individuals which are typically recorded in large cross-sectional surveys.[11] Therefore, to calculate welfare changes in practice, it is necessary to decide on an appropriate method of dealing with individuals, based on an estimated form of the stochastic term's distribution.[12] Here a

[11] For a detailed introduction to modelling, estimation and microsimulation methods, see Creedy and Kalb (2005a).
[12] Preston and Walker (1999) and Dagsvik and Karlström (2005) used an analytical approach to derive the expressions for expected welfare.

simulation approach is suggested for calculating expected welfare, based on the 'calibration' method used in simulating policy reforms. This method is described below.

If a random draw is taken from the relevant error term distribution for an individual, the utility values arising from this draw (the random utility component) combined with the deterministic component of the utility function (using point estimates of the utility parameters and observed characteristics) can be computed. Comparing the utility values at each labour supply point, optimal labour supply can be determined; that is the discrete hours level which maximises utility. The main feature of the approach used here is the use of calibration, whereby a number of random draws of error terms are obtained and the associated optimal labour supplies are determined. Only those error terms resulting in the implied optimal hours being equal to the observed labour supply in the pre-reform tax system are retained. When applied to a new tax and transfer system giving rise to a new set of net incomes for each hours level, each draw produces a single optimal post-reform hours level. Hence, the welfare change is computed for each accepted draw, following the procedure outlined in the previous section. Pre-reform hours are thus always equal to observed hours but, using the preserved set of error terms, a frequency distribution of post-reform hours arises. Consequently a frequency distribution of welfare changes can be obtained for each individual. The individual's expected welfare change is then calculated as the arithmetic mean value. This is strictly the mean of a conditional distribution. That is, it is subject to the individual being placed at the observed hours before the policy change.[13]

In describing the calibration method, it is useful to distinguish between 'draws' and 'tries' when selecting from the error distribution. A specified number of 'tries' are used to obtain an error term which makes the individual's resulting optimal hours equal to observed hours: the successful 'try' is then retained and referred to as a 'draw'. A specified number of 'draws' is retained for computing the expected value of the (conditional) distribution of the welfare change. In many cases only a small number of 'tries' are actually needed to produce each 'draw'. However, for some individuals, it may not be possible to obtain a successful 'draw' within the prescribed number of tries.[14] In such a case, labour supply is considered to

[13] The calibration approach is preferred as it uses important information in the sample about each individuals' actual labour supply in a given tax structure. The resulting expected welfare change is also easily interpreted, as starting from a single hours level. This contrasts with any approach using simply a set of random values from the error distribution, giving a frequency distribution over hours for the pre-reform system, as described for example by Small and Rosen (1981).

[14] The number of such unsuccessful draws is quite small in the model described below. Using the method of generating conditional draws described in Bourguignon, Fournier and Gurgand (1998) the number of unsuccessful draws could be reduced to zero.

be unchanged and the compensating variation for that draw is computed by taking the difference between net incomes at the observed hours point.

3.2 Quadratic Utility Functions

The general procedure described above can be applied in a straightforward manner to the quadratic direct utility function. The quadratic utility function has been used in empirical analyses of labour supply in the context of discrete hours models; it is used in the MITTS model and in the empirical examples in this paper.[15] The quadratic direct utility function takes the form:

$$U = \alpha c^2 + \beta h^2 + \gamma ch + \delta c + \varepsilon h \qquad (5)$$

In order to obtain the welfare change measures, it is required to compute net income, c, corresponding to a specified hours level, h, along an indifference curve with known utility level, U_0^i (computed from net income and hours at the optimal position). This is obtained as the appropriate root of the quadratic:[16]

$$Ac^2 + Bc + D = 0 \qquad (6)$$

with:

$$\begin{aligned} A &= \alpha \\ B &= \gamma h + \delta \\ D &= \beta h^2 + \varepsilon h - U_i^0 \end{aligned} \qquad (7)$$

In practice the appropriate root is obvious. If $\alpha < 0$ in all cases, it is equal to the smaller root, since this places the solution on the section of the utility function which increases with net income, c. The other solution is located on the downward sloping section of the utility function. The fact that the quadratic utility function can be downward sloping over a range of c values may give rise to difficulties when computing welfare measures. That is, in some cases there may be no solution to the quadratic corresponding to the optimal utility before the policy change, U_0^i. The utility function can become downward sloping before reaching U_0^i, in particular for some of the higher discrete hours levels which may require very high net income to compensate for the high labour supply levels. Comparisons between net incomes on the post-reform budget constraint and the net incomes required to reach the pre-reform optimal utility curve need to be made at all levels of labour supply, not simply at the

[15] Examples include Keane and Moffitt (1998) and Duncan and Weeks (1997, 1998).
[16] See Creedy (2001) for derivation and further details of the quadratic utility function.

observed hours level where the problem is unlikely to arise. This is discussed in the following paragraphs, along with other details regarding the practical implementation of the approach.

The quadratic utility function is not automatically increasing with income across the full labour supply range. That is, the quadratic specification implies that there is a turning point where the utility function turns from increasing with net income (consumption) to decreasing with net income. For all income units, the function is increasing with income at the observed labour supply and for virtually all labour supply points the utility function is increasing with income under the relevant budget constraint.[17] However, further increases in net income are not guaranteed to remain below the income at which the utility function turns from increasing to decreasing with income.

Therefore, in the search for the equivalent and compensating variations using quadratic utility functions, a check is made at each labour supply point to ensure that the relevant range of the utility function implies increasing utility when net income increases. If the condition is violated before the desired utility is reached, the particular point is ignored. These points tend to represent the higher levels of hours worked. This could be interpreted as an indication that working too many hours may prevent some individuals from reaching utility levels above a particular threshold, independent of the income they receive. In those cases, the disutility due to limited leisure time may no longer be compensated by more net income.

An indication of the extent to which the above condition is violated is given in Table 1, using the MITTS model applied to a policy reform involving a five percentage point increase in all positive income tax rates. This policy is described and examined in more detail in the next section. For single individuals, 11 discrete labour supply points are used and 100 sets of error terms are drawn to produce the probability distribution of post-reform labour supply.[18] This means that for each individual, 1100 equations involving the quadratic utility function need to be solved. For each couple family, labour supply choices of the two partners are simultaneously determined. Couples can choose from 66 hours combinations, made up of 6 labour supply points for partnered men and 11 points for partnered women; hence 6600 equations have to be solved for each couple.

[17] Only for one income unit was a labour supply point found for which the predicted income was located on the downward slope of the utility function. This particular point was treated like the hours points without a solution and was thus ignored in the computation of welfare changes.

[18] For each draw, 1000 tries are allowed, although usually much fewer tries are required.

The results from running this policy simulation show that there are relatively few points where there is no feasible solution. As reported in Table 1, they concern about 1.4 per cent of the total number of equations that need to be solved and 21.7 per cent of all income units are affected for at least one of their equations.

Table 1 Distribution and frequency of no-solution cases by demographic groups

Income unit (IU) type	Per cent of IU with at least one equation without solution	Per cent of equations without solution (for IU with at least one equation without a solution)	Per cent of equations without solution (for all equations and for all IU)
Couples	0.00	0.00	0.00
Single men	5.49	0.15	0.01
Single women	96.21	7.16	6.89
Single parents	16.71	2.59	0.43
All	21.73	6.37	1.38

Table 1 shows that there are no no-solution cases for couples, but in 6.89 per cent of the equations there is no solution for single females and 96.2 per cent of all single women are affected. That is, on average 76 out of the 1100 equations have no solution for single women.

Table 2 shows that the equations for which no solution can be found occur at labour supply points representing at least 20 hours of work per week and are most prevalent at the 45 and 50 hours points. Ranking single women by the proportion of equations for which no solution is found and examining the average characteristics for each decile of no solution proportions, the following observations can be made. The highest proportion of no-solution equations are found amongst younger women. Unemployed single women and part-time workers are also more likely to be affected.

Table 2 Percentage of equations without solution by labour supply point

Discrete hours points in hours per week	Single males	Single females	Sole parents
0, 5, 10 and 15	0.00	0.00	0.00
20	0.00	0.00	0.01
25	0.00	0.01	0.03
30	0.00	0.09	0.07
35	0.00	0.72	0.16
40	0.00	2.58	0.46
45	0.00	12.46	1.19
50	0.06	25.78	2.15

The larger occurrence of no-solution points for single women can be explained by comparing the parameter estimates in their utility function with those for the other groups.

Single women tend to have a much lower preference for income relative to their preference for leisure time. This preference for income tends to decrease more steeply with hours of work compared to the other groups. The preference for income increases with age and is therefore at its lowest level for the youngest group of single women. As a result, it is more difficult to compensate single women (particularly if they are young) at higher labour supply levels with sufficiently high incomes so they are returned to the original optimal utility.

The optimal utility level is likely to have been at an observed labour supply level which was lower than the relevant labour supply point for which no solution can be found. Since the lowest compensation possible is required, these points at which no solution can be found due to low preferences for income are not relevant, because they will not result in the lowest compensation across all labour supply points.

3.3 Social Evaluations

The method described above can be used to obtain the expected welfare change for each individual or couple in the database used in a microsimulation model. These can be used to obtain excess tax burdens and marginal welfare costs for each income unit. Direct comparisons of welfare changes and net income changes can also be made. However, it is often desired to evaluate tax reforms in terms of their effects on specified demographic groups or for the population as a whole.[19] First, it must be recognised that in many behavioural microsimulation models, the labour supply responses of some individuals – such as the retired, disabled and students – are not calculated. For such individuals, the welfare change is equated to the net income change.

In addition, population-level evaluations necessarily involve value judgements, so that a decision must be made regarding the social evaluation method. Any evaluation for a broad group of income units necessarily involves comparisons of units of different size and composition. Value judgements concern three aspects: the welfare metric, the definition of the unit of analysis and the form of the social welfare function to be used. The latter is closely related to value judgements regarding inequality aversion and the implied inequality measure. The empirical section reports results based on the use of money metric utility per adult equivalent, using the Whiteford equivalence scales reported by Binh and Whiteford (1990), and using the individual as the unit of analysis.

The steps in the social evaluation are as follows. For each income unit, the initial

[19] Income unit weights provided by the Australian Bureau of Statistics with the Survey of Income and Housing Cost data are used in the empirical analysis to obtain aggregate measures at the population level.

money metric utility, M_0, is obtained, using pre-reform taxes as 'reference prices'; this is equal to full income under the pre-reform system. Given the approach used to calculate *EV* and *CV*, taking into account the non-linearity and non-convexity of the budget constraint, an approach consistent with this approach is used to calculate M_0. For each income unit, the net income at 80 hours of work by all adult members of the income unit under pre-reform taxes is calculated. Assuming that 80 hours is the maximum number of hours that can be worked per week, this net income represents full income for the income unit. Then, given the expected equivalent variation, *EV*, resulting from the reform, expected post-reform money metric utility is computed as $M_1 = M_0 - EV$. For each income unit, the adult equivalent size, *s*, is obtained using a set of equivalence scales, which is used to compute money metric utility per adult equivalent, m_{ji}, where *j* refers to the tax structure and *i* refers to the income unit. The distributions of m_{0i} and m_{1i} can be used to make social evaluations.

With the individual as the unit of analysis, in computing inequality measures each value of m_{ji} is weighted by the unadjusted number of persons in the income unit, n_i.[20] This paper uses Atkinson's inequality measure, $A(\varepsilon)$, where ε is the degree of relative inequality aversion. The inequality measure is expressed as 1 minus the ratio of the equally distributed equivalent value to the arithmetic mean. The equally distributed equivalent value is the value which, if obtained by everyone, gives the same social welfare as the actual distribution. Using an additive welfare function based on constant relative aversion, the equally distributed equivalent value is in general, for a set of values y_i, for $i=1,\ldots,n$, equal to:

$$\left(\frac{1}{n} \sum_{i=1}^{n} y_i^{1-\varepsilon} \right)^{1/(1-\varepsilon)}$$

In the present context an adjustment must of course be made for the weighting by the number of persons in each household. Results can be obtained for a range of inequality aversion parameters, ε. Finally, social welfare in each system is obtained using the abbreviated welfare function, $W = \bar{m}\left(1 - A(\varepsilon)\right)$, which is associated with the Atkinson inequality measure (and where $\bar{m}$ is the arithmetic mean value of *m*). It is then possible to compare results based on money metric utility with those obtained using net incomes in the social welfare function.

[20] In addition, the survey weights mentioned in the previous footnote are used for grossing-up purposes.

4 The Approach Applied to Income Tax Increases

To illustrate the approach outlined in the previous two sections, two hypothetical policy changes involving increasing income taxation rates have been designed. The starting point is the social security and income tax system which was in place in Australia in January 2001. This involved no tax up to AU$6,000, 17 per cent tax between AU$6,001 and AU$20,000, 30 per cent tax between AU$20,001 and AU$50,000, 42 per cent tax between AU$50,001 and AU$60,000, and 47 per cent tax from AU$60,001 onwards.

In the first policy change, all positive income tax rates are increased by 5 percentage points. In the second policy change, all income tax rates (including the tax-free range) are increased by 15 percentage points. These policy changes are evaluated using the Melbourne Institute Tax and Transfer Simulator (MITTS), which can compute the aggregate and individual effects on households in Australia (see the Appendix). Examples of the effect of the first policy change on specific income units are provided in subsection 4.1. Overall results aggregated to the demographic group level are reported in subsection 4.2 for both policy changes. Subsection 4.3 presents results for the first policy change by different subgroups, while distinguishing between individuals with positive and zero *EV*.

4.1 Individual Results

First, consider welfare changes for particular income units. Table 3 shows outcomes resulting from the first policy change (all positive rates increased by 5 percentage points), for one typical income unit from each of the household types representing low, medium and high income levels. In each case the higher tax rates imply reductions in expected hours worked and net incomes. The increase in tax paid when allowance is made for the labour supply response is, as expected, much smaller than if labour supply is fixed.

The table shows large variations in the marginal welfare cost of taxation, defined as the marginal excess burden (in terms of the equivalent variation) per dollar of extra tax paid.[21] Furthermore the marginal welfare costs are substantial, the efficiency cost per extra dollar in many cases exceeding one dollar. For example, the marginal welfare cost for the medium-income single woman shown is $3.20 per extra $1 of tax raised, and is as high as $5.40 for the medium-income single parent shown. This arises despite small expected reductions in labour

[21] Here, the marginal excess burden is calculated as the equivalent variation from the policy change less the extra tax paid. This is not, strictly speaking, the accurate form of the excess burden. This is because the difference between the new revenue and the tax which would be paid under the old rates but at the new utility level should be used instead of simply the extra tax. However, this would be difficult to calculate since gross income at the new utility level would be required.

Table 3 Examples of Individual Results (in $ per year, except age and hours worked)

	Couples	Single men	Single women	Single parents
LOW INCOME				
Age	60, 50	30	20	40
Net income (pre-reform)	24,893	11,705	11,730	13,227
Net income (post-reform)	24,064	11,348	11,295	12,687
Change in net income	-828	-357	-435	-540
Net Government Revenue (Labour supply fixed)	594	335	336	426
Net Government Revenue (including labour response)	150	290	182	128
Hours worked per week	20, 12	25	21	15
Expected hours change in hours per week	-0.80, -0.40	-0.25	-0.40	-0.60
Compensating variation	581	332	332	416
Equivalent variation	581	332	333	416
Marginal Welfare Cost	2.9	0.1	0.8	2.3
Difference between Net Income change and *EV* (in %)	-29.9	-7.0	-23.6	-22.9
MEDIUM INCOME				
Age	35, 35	45	45	25
Net income (pre-reform)	39,457	17,503	16,330	23,685
Net income (post-reform)	37,427	16,648	15,437	22,916
Change in net income	-2,031	-855	-893	-769
Net Government Revenue (Labour supply fixed)	1,850	703	630	244
Net Government Revenue (including labour response)	1,626	455	149	37
Hours worked per week	46, 6	40	27	13
Expected hours change in hours per week	-0.40, -0.10	-0.80	-1.00	-1.35
Compensating variation	1,839	690	615	232
Equivalent variation	1,843	691	626	233
Marginal Welfare Cost	0.1	0.5	3.2	5.4
Difference between Net Income change and *EV* (in %)	-9.3	-19.2	-29.9	-69.7
HIGH INCOME				
Age	45, 40	45	40	35
Net income (pre-reform)	85,621	38,669	34,716	61,249
Net income (post-reform)	76,902	35,490	32,074	55,915
Change in net income	-8,719	-3,179	-2,642	-5,334
Net Government Revenue (Labour supply fixed)	5,569	2,271	1,970	4,245
Net Government Revenue (including labour response)	3,218	1,490	1,416	2,708
Hours worked per week	46, 40	35	50	45
Expected hours change in hours per week	-1.30, -3.26	-1.15	-1.35	-1.30
Compensating variation	5,346	2,220	1,866	4,159
Equivalent variation	5,483	2,248	1,938	4,246
Marginal Welfare Cost	0.7	0.5	0.4	0.6
Difference between Net Income change and *EV* (in %)	-37.1	-29.3	-26.6	-20.4

supply. A further observation is that the differences between net income changes and equivalent variations are substantial, and vary considerably among units. The biggest difference, of almost 70 per cent, is for the medium-income single parent while the smallest difference is for the low-income single man.[22]

4.2 Aggregate Results

Table 4 presents the aggregate effects of the policy changes. These are calculated by adding all *EV*, *CV* and net incomes across all income units without equivalising the amounts. In terms of social evaluations, the concentration on aggregates can be regarded as equivalent to the assumption of zero relative inequality aversion. The first policy change would reduce government expenditure by just under AU$14 billion and the second by just over AU$50 billion. After allowing for labour supply responses, the savings from the policy changes are reduced to just under AU$11 billion and just over AU$40 billion due to a decrease in labour supply arising from the income tax increases. In the first policy change, the expenditure on single parents after accounting for labour supply changes is higher than it was before the tax increase. That is, after accounting for the labour response, the increase in tax revenue was less than the increase in family payments and social security payments due to the reduced labour supply.

Table 4 The aggregate effects of increases in income taxation rates (in $m per year)

	Couples	Single men	Single women	Single parents	Total
Increase in all positive income tax rates by 5 percentage points					
Net government revenue change (Labour supply fixed)	9,699	2,307	1,338	325	13,669
Net government revenue change (incl. labour response)	8,013	1,977	1,100	-100	10,991
Average hours change in hours per week	-0.38, -042	-0.30	-0.26	-1.53	-0.41
Compensating variation	9,591	2,283	1,308	304	13,486
Equivalent variation	9,639	2,296	1,333	312	13,579
Marginal welfare cost	0.20	0.16	0.21	- [a]	0.24
Aggregate net income change	-11,417	-2,624	-1,540	-622	-16,203
Difference between net income change and *EV* (in %)	-15.6	-12.5	-13.4	-49.9	-16.2
Increase in all income tax rates by 15 percentage points					
Net government revenue change (Labour supply fixed)	34,906	8,638	5,158	1,480	50,182
Net government revenue change (incl. labour response)	34,314	8,538	5,156	1,379	49,386
Average hours change in hours per week	-1.20, -1.44	-0.96	-0.63	-4.15	-1.27
Compensating variation	33,757	8,374	4,847	1,298	48,275
Equivalent variation	34,314	8,538	5,156	1,379	49,386
Marginal welfare cost	0.21	0.16	0.15	8.44	0.22
Aggregate net income change	-39,651	-9,465	-5,556	-2,161	-56,833
Difference between net income change and *EV* (in %)	-13.5	-9.8	-7.2	-36.2	-13.1

Note a: The net government revenue change (including expenditure on social security) is negative for this group.

[22] Not surprisingly, there are some units for which the expected reduction in labour supply is such that there is a reduction in tax paid as a result of the tax rate increase. This means that the individual is on the 'downward sloping' or 'wrong' side of the Laffer curve.

A positive value for the compensating or equivalent variation indicates a welfare loss. The equivalent and compensating variations are close in value, since the price of leisure time (or the net wage) before and after the reform is similar. With an increase in the tax rate with 15 percentage points, the difference between the old and the new price increases. Therefore, the values for the compensating and equivalent variations, which are expressed in the new and old price respectively, become more different.[23]

In relative terms, similar to the specific results in Table 3, the marginal excess burden as represented by the marginal welfare cost is particularly high for single parents due to their relatively low incomes, the more generous social security payments available to them, and the larger labour responses compared to other groups. In the case of the 5 percentage point increase in tax rates, for single parents the marginal welfare cost is affected by the fact that there is an expected decrease in tax revenue from the policy change. As a result, no sensible marginal welfare cost can be calculated in this case. Single parents are worse off in terms of welfare and the government is expected to collect less net revenue (consisting of income tax minus income support payments) from this group than before the change.

The final line of the two segments of Table 4 provides comparisons between average welfare measures, in terms of the equivalent variation and average net income measures. The change in net income clearly exceeds the welfare change measure. The average gap between the two sets of changes is expressed as a percentage of the aggregate net income change. The relative differences vary among unit types and policy changes (although the relative difference does not appear to be driven by the size of the policy change) and are typically large, particularly for single parents. This means that potentially different conclusions could be drawn with regard to how the different groups and individuals in the population are affected, depending on whether net income changes or welfare changes are considered.

Summary information regarding social welfare functions is given in Table 5, for each of the two policy changes and three values of relative inequality aversion ε. Under all specified measures, social welfare and inequality (as measured by the Atkinson's index) decrease as a result of the tax increases, but the use of net income produces much higher reductions than the use of money metric utility. This arises because of the failure to value leisure time in measures based on net income only.

[23] An increase in the tax rate results in lower prices for leisure after the policy change.

The magnitude of the reductions in the Atkinson's index decreases as the relative inequality aversion ε increases when the index is based on money metric utility. Conversely, the reductions in the Atkinson's index tend to increase as ε increases when the index is based on net income, especially for the second policy change. Different conclusions may thus be drawn if the welfare implications of changes in leisure and home production time are ignored. To explore differences in implications depending on whether money metric utility or net incomes are used in the social welfare function, the results in Table 5 are disaggregated by demographic group in Table 6.

Table 5 Social Welfare Function Evaluations

	Mean	Atkinson's index			Social Welfare			Gini
		ε = 0.2	ε = 0.8	ε = 1.4	ε = 0.2	ε = 0.8	ε = 1.4	
Pre-reform money metric	51,979	0.0151	0.0569	0.0951	51,192	49,021	47,035	0.2080
Pre-reform net income	22,850	0.0282	0.1047	0.1710	22,205	20,459	18,943	0.2913
Increase in all positive income tax rates by 5 percentage points								
Post-reform money metric	50,952	0.0146	0.0548	0.0917	50,210	48,161	46,279	0.2039
% change	-1.98	-3.85	-3.72	-3.57	-1.92	-1.76	-1.61	-1.97
Post-reform net income	21,617	0.0258	0.0955	0.1561	21,060	19,552	18,243	0.2777
% change	-5.40	-8.62	-8.73	-8.70	-5.16	-4.43	-3.70	-4.66
Increase in all income tax rates by 15 percentage points								
Post-reform money metric	48,263	0.0136	0.0513	0.0863	47,606	45,785	44,099	0.1970
% change	-7.15	-10.08	-9.76	-9.30	-7.01	-6.60	-6.24	-5.30
Post-reform net income	18,545	0.0211	0.0778	0.1270	18,154	17,102	16,189	0.2486
% change	-18.84	-25.22	-25.64	-25.69	-18.25	-16.41	-14.54	-14.65

Note: Money metric and net income are per adult equivalent. Social Welfare is the equally distributed equivalent level of money metric (or net income) in $ per year.

The size of the percentage reductions in the Atkinson's index based on money metric utility is lower for higher relative inequality aversion, for all demographic groups. However, when net income is used, the reductions in the Atkinson's index can either increase (as is the case for couples) or decrease (single men and single women) as relative inequality aversion increases. Moreover, the ranking of the demographic groups changes with the choice of net income or money metric utility. Although inequality reductions are the highest (by a large margin) for single parents when using net income, the decreases in inequality are the smallest for this specific group when money metric measures are used. Likewise, the ranking of couples and single men in terms of inequality changes is reversed if money metric utility is used instead of net income.

Table 6 Social Welfare Function Evaluations Disaggregated by Demographic Group

	Mean	Atkinson's index			Social Welfare			Gini
		ε = 0.2	ε = 0.8	ε = 1.4	ε = 0.2	ε = 0.8	ε = 1.4	
Couples								
Pre-reform money metric	57,046	0.0129	0.0473	0.0771	56,307	54,345	52,647	0.1893
Post-reform money metric	55,861	0.0124	0.0456	0.0744	55,165	53,314	51,706	0.1854
% change	-2.08	-3.85	-3.73	-3.54	-2.03	-1.90	-1.79	-2.04
Pre-reform net income	24,550	0.0270	0.0990	0.1601	23,888	22,119	20,620	0.2838
Post-reform net income	23,145	0.0248	0.0908	0.1466	22,572	21,044	19,752	0.2714
% change	-5.72	-8.10	-8.30	-8.40	-5.51	-4.86	-4.21	-4.38
Single men								
Pre-reform money metric	45,193	0.0115	0.0448	0.0772	44,671	43,167	41,705	0.1814
Post-reform money metric	44,220	0.0109	0.0426	0.0736	43,738	42,337	40,963	0.1766
% change	-2.15	-5.39	-4.96	-4.56	-2.09	-1.92	-1.78	-2.68
Pre-reform net income	21,640	0.0325	0.1253	0.2104	20,936	18,929	17,087	0.3164
Post-reform net income	20,528	0.0299	0.1152	0.1940	19,915	18,163	16,545	0.3033
% change	-5.14	-8.10	-8.04	-7.78	-4.88	-4.04	-3.17	-4.14
Single women								
Pre-reform money metric	40,229	0.0110	0.0427	0.0734	39,788	38,512	37,277	0.1811
Post-reform money metric	39,587	0.0104	0.0405	0.0698	39,175	37,984	36,824	0.1759
% change	-1.60	-5.28	-5.13	-4.90	-1.54	-1.37	-1.21	-2.89
Pre-reform net income	18,082	0.0274	0.1049	0.1748	17,586	16,185	14,921	0.2918
Post-reform net income	17,340	0.0248	0.0952	0.1594	16,910	15,690	14,576	0.2771
% change	-4.10	-9.57	-9.29	-8.79	-3.84	-3.06	-2.32	-5.03
Single parents								
Pre-reform money metric	36,477	0.0167	0.0628	0.1026	35,866	34,186	32,733	0.2277
Post-reform money metric	36,146	0.0163	0.0613	0.1003	35,555	33,929	32,521	0.2249
% change	-0.91	-2.39	-2.35	-2.29	-0.87	-0.75	-0.65	-1.22
Pre-reform net income	17,135	0.0128	0.0480	0.0785	16,916	16,314	15,790	0.1954
Post-reform net income	16,470	0.0107	0.0399	0.0654	16,294	15,812	15,392	0.1765
% change	-3.88	-16.67	-16.76	-16.65	-3.68	-3.07	-2.52	-9.70

Note: Money metric and net income are per adult equivalent. Social Welfare is the equally distributed equivalent level of money metric (or net income)

The results in Table 6 show that although all welfare changes are negative, the ranking of the demographic groups changes with the relative inequality aversion index. In addition, and, similar to the inequality measures, the ranking of the demographic groups changes with the choice of net income or money metric utility in the social welfare function. When only income is considered, single parents appear slightly worse off than single women after the policy change (except under lower relative inequality aversion values). However, when the value of leisure and home production time is taken into account, single parents have the lowest decrease in social welfare. The increase in leisure and home production time partly compensates for the reduced net income.

Two reasons can be given to explain why the relative reductions in social welfare are consistently higher when using net income. First, absolute net income changes are on average higher than welfare changes (as shown in Table 4) because the latter take into account the increase in leisure and home production time. Second, initial social welfare values are lower when using net income. As a result, higher relative changes are obtained for net income based welfare measures than for money metric utility based welfare measures even if absolute changes were similar in size.

4.3 Welfare Changes for Subgroups

For different subgroups in the population, Table 7 examines the average welfare changes and compares these to the average net income changes for the first policy change. Those for whom $EV = 0$ are below the tax-free threshold and are not affected by the tax rate change. Since the comparisons are across households of different sizes, the welfare and income measures are equivalised using the Whiteford equivalence scale. The net income changes and the equivalent variations (or the compensating variations) are not necessarily the same even for individuals without a labour supply response. The existence of unchanged Marshallian labour supply does not necessarily imply the absence of an excess burden. Furthermore, an equivalent (or compensating) variation larger or smaller than the net income change in absolute terms may be found at another labour supply point than the observed labour supply point, even if utility is still optimal at the original observed labour supply. In addition, differences between the two measures in Table 7 could arise for individuals without labour response because individuals' partners in couple households may have changed their labour supply. Nevertheless, the difference is clearly less for the group who did not change labour supply than for the groups who changed their labour supply.

Couples are affected to the largest degree in terms of the proportion of households affected and in terms of the average decrease in net income and equivalent variation. This is due to the fact that couple households are on average at a higher income level than the other groups. Percentage wise, single parents are the least affected but if they are affected their decrease in net income is relatively large. The difference between the net income change and equivalent variation is largest for single parents. This indicates that they have been more able than the other three groups to compensate for the loss in utility caused by the income loss by increasing leisure and home production time, which has translated in more substantial negative labour supply responses (see Table 5).

As expected, those working full-time are more likely to be affected than the other groups and they have a larger decrease in net income and welfare if they are affected. The unemployed are least likely to be affected, followed by the non-participants including those who are retired and/or have other sources of income than from labour supply. The average income changes for non-participants and unemployed, if they are affected, are similar, but the corresponding welfare losses are clearly lower for the unemployed than for non-participants.

Table 7 The effect of an increase in tax with 5 percentage points for all positive tax rates

	EV > 0			*EV* = 0	TOTAL	
By income unit type	% of IU	Income change per adult equivalent ($/year)	*EV* per adult equivalent ($/year)	% of IU	Income change per adult equivalent ($/year)	*EV* per adult equivalent ($/year)
Couples	80.5	-1,671	1,409	19.5	-1,405	1,185
Single men	70.1	-1,585	1,387	29.9	-1,111	972
Single women	54.3	-1,367	1,183	45.7	-742	642
Single parents	47.1	-1,480	735	52.9	-666	331
By labour force status						
Full time	97.7	-1,872	1,558	2.3	-1,829	1,522
Non-participant	24.6	-676	660	75.4	-166	162
Part-time	85.8	-888	786	14.2	-762	675
Unemployed	13.6	-658	575	86.4	-89	78
By labour supply response						
Working more	100.0	-2,094	1,605	0.0	-2,094	1,605
No change	55.2	-1,156	1,145	44.8	-638	632
Working less	100.0	-1,980	1,790	0.0	-1,980	1,790
TOTAL	70.1	-1,627	1,356	29.9	-1,233	1,027

Similar patterns are observed when disaggregating by income unit type, labour force status and labour supply response for the other policy change. One result, from a disaggregation of the results for an alternative policy change of decreasing tax rates, is worth mentioning as it clearly illustrates the potential for different conclusions regarding the impact of policy changes depending on the measure being used. Consider a policy change in which all positive income tax rates are decreased by 5 percentage points, rather than the first policy above where they are increased. Similar outcomes of $656, $754 and $751 are observed for the net income change among those who were non-participants, part-time workers or unemployed respectively before the change. However, the equivalent variations are very different at -$293, -$503 and -$78 respectively. Based on net income changes, the conclusion would be that part-time workers and unemployed are equally affected, with the non-participants not far behind. Taking into account the changes in labour supply, the unemployed and non-participants still gain but to a lesser extent than would be inferred from the net income changes.

The reason for this clear difference between the two measures for the tax decrease is that a decrease in tax rates encourages non-workers to enter the labour market. This affects the group of non-participants and unemployed individuals, who are likely to experience stronger positive labour supply responses than the part-time and full-time workers (some of whom may even decrease their labour supply). The increased labour supply reduces the non-workers' utility levels and thus their equivalent variations. An increase in tax has the opposite effect, making it less likely that non-participants and unemployed individuals, who were not working before the reform, enter the labour market after the reform. That is, when tax rates increase, these non-workers are unlikely to change their labour supply behaviour, resulting in a net income change and an equivalent variation which are much more similar.

The above results show that different conclusions may be reached regarding the group affected to the largest degree by a policy change depending on whether net income changes or welfare changes are measured. The advantage of using welfare changes in the evaluation of policy changes is that it takes into account the value of leisure or home production time. A microsimulation model that allows for labour supply responses would therefore benefit from the inclusion of welfare measures in order to evaluate the value of an increase or decrease in leisure time to the households.

5 Conclusions

This paper has examined the calculation of compensating and equivalent variations in the context of labour supply modelling, where highly nonlinear budget constraints are common. In an earlier paper, it was shown that the standard method of computing welfare changes may not give appropriate values (Creedy and Kalb, 2005b). This arises if the computation involves hours levels for which the linearised virtual budget constraint indicates a different net income compared with the exact nonlinear budget constraint, or when corner solutions are involved. A method of calculating exact welfare changes, allowing for the full detail of the budget constraint, was discussed in the context of discrete hours models. Discrete hours models have gained importance because they are being more widely adopted as a result of their substantial advantages in preference estimation.

The implementation of the method in the context of microsimulation, using econometrically estimated direct utility functions for particular demographic groups, was examined here. A method of producing (conditional) average welfare changes for each individual was proposed, based on the use of 'calibration' to ensure that, for all individuals, their optimal labour supply before a hypothetical tax change is equal to the observed (discretised) labour supply reported in the dataset. The special case of quadratic direct utility functions, which are widely used in labour supply modelling, was discussed and used in the empirical example.

To illustrate the use of the approach in microsimulation, two policy changes involving tax increases of different magnitudes were simulated. An advantage of using welfare change measures is that they can take into account the value of leisure or home production time. This advantage is of particular importance in policy evaluations which allow for labour supply responses. Therefore, measured differences between evaluations using welfare measures and those obtained using only changes in net incomes were examined. The results from the practical examples show that very different conclusions may be reached regarding individual comparisons, overall comparisons using social welfare functions and identification of those demographic groups affected to the largest degree by a policy change, depending on whether net income changes or welfare changes are measured. It was found that the marginal excess burden can take a wide range of values for individuals and subgroups in the population. Substantial marginal welfare costs associated with an increase in income tax rates were measured, in particular for single parents.

Given the increasing use of behavioural microsimulation models in tax and social security policy evaluations, which are usually based on discrete choice labour supply models, the procedures outlined in this paper offer considerable scope for extending the range of analyses and measures generally used to judge the effects of proposed reforms. These new procedures allow the evaluation of any changes in leisure and home production time available to the income units in addition to the usual evaluation of changes in disposable income due to policy reforms.

The Appendix: Microsimulation Modelling

We use MITTS, a microsimulation model, to calculate the effect of two alternative tax changes. The expected effects presented in this paper are based on estimated parameters for a structural labour supply model, which is described in more detail in Kalb (2002). That is, the labour supply effects are not actually observed but based on simulations. A more detailed general description of the behavioural microsimulation modelling approach used in this analysis can be found in Creedy and Kalb (2005a) and specific information on MITTS can be found in Creedy *et al.* (2002, 2004).

The microsimulation is based on a sample of representative Australian households in the 2000/2001 SIHC. This is a survey of the Australian population at the time of the policy change of interest. Detailed information is available on each household and on the individuals in the households. This allows us to replicate the social security payments received and income tax paid for each individual and household according to the income tax and social security rules at any point in time or according to a hypothetical set of rules. Using the weights provided by the ABS, the sample can be weighted to obtain population amounts.

A static simulation of the effects of a tax change involves the use of alternative budget constraints in the pre- and post-reform situation. The budget constraints incorporate all main tax and transfer programs —in this paper, as they were in January 2001 (pre-reform) and in January 2001 including the hypothetical tax changes (post-reform)— and are computed using MITTS. Assuming unchanged labour supply, MITTS can calculate the net income of each individual before and after the change together with the social security payments which are received and income tax which is paid. From these individual amounts, aggregate expenditure and revenue can be computed using the ABS-provided weights to inflate sample totals into population totals.

In the behavioural simulation, in which labour supply is allowed to change in response to a policy change, MITTS calculates net incomes for each household at all predetermined discrete labour supply points based on the wage rates of individuals (either observed in the data or imputed, using the estimated wage equations as described in Kalb and Scutella (2002)), other income, and some individual and household characteristics. As in the static simulation, the net incomes can be calculated imposing different tax and transfer systems, allowing hypothetical and real policy changes to be analysed. Together with the net incomes at all labour supply points, the estimated parameters from the structural labour supply model are key inputs in the behavioural component of the microsimulation model. They allow us to simulate the labour supply responses of the policy change. The behavioural labour supply responses presented in this paper are based on a quadratic utility function with preference parameters which are allowed to vary with an individual's characteristics. The approach follows the discrete choice approach taken by Van Soest (1995) and Blundell *et al.* (2000).[24]

The behavioural simulation begins by recording the discrete hours level for each individual that is closest to their observed hours level.[25] Then, given the parameter estimates of the utility function (which vary according to a range of demographic characteristics), a random draw is taken from the distribution of the 'error' term. This draw is rejected if it results in an optimal hours level that differs from the discretised value observed before the reform, otherwise the draw is accepted.[26] The accepted drawings are then used to determine the optimal hours level after the policy change. A total of 100 'successful draws' (that is, drawings which generate the observed hours as the optimal value under the base system for the individual) are produced. Conditional on this set of random draws, a probability distribution over the set of discrete hours for each individual under the new tax and transfer structure is generated.[27] Thus the same error terms, representing the random utility component which is for example due to unobserved factors, are used before and after the reform. However, the tax and transfer system is changed in the reform, which changes net household incomes, and as a result changes the deterministic utility levels and potentially the optimal level of labour supply. The labour supply after the reform is calculated as the average outcome across all draws of the error terms.

[24] As Blundell *et al.* note, the discrete choice labour supply model has become increasingly popular. Given the aim of simulating policy changes with regard to the tax and transfer system and assessing its effect on labour supply, a discrete model specification of labour supply choice is chosen to enable us to deal with the full detail of the tax and transfer system. In other regards, the model has been kept relatively simple; for example no explicit home production is included.

[25] Labour supply is kept constant for some groups who are expected to differ in their responses (that is, be less responsive) compared to the average working-age individual. These groups are the self-employed, those on disability payments, full-time students and people over 65 years of age.

[26] The optimal hours level is the labour supply where the utility of an individual is at a maximum.

[27] See Creedy and Kalb (2005a) for a detailed description of the estimation, specification and simulation in behavioural microsimulation modelling.

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