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Publication details:
Working Paper No. 82
SPRC Discussion Paper
0733404685 (ISBN)
1447-8978 (ISSN)

Publication Date:
1998

DOI:
https://doi.org/10.26190/unsworks/213

Social Policy Research Centre

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by Guyonne Kalb

SPRC Discussion Paper No. 82
June 1998

ISSN 1037 2741
ISBN 7334 0468 5

An earlier version of this paper was presented at the Labour Econometrics Workshop at the Australian National University, Canberra, 3-4 April 1998. The author would like to thank Tony Eardley, Denzil Fiebig, Tim Fry, Paul Miller and Alan Powell and the workshop participants for their comments. None of these are responsible for any errors of fact or interpretation.

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The series is indebted to Diana Encel for her continuing editorial contribution.

Tony Eardley
Editor

Abstract

In this paper, a simultaneous discrete choice model for welfare participation and labour supply of two-adult households is estimated. It is assumed that in addition to the indirect effect of welfare participation on utility, welfare participation also has a direct effect. The resulting net effect is unknown and may depend on personal characteristics. To account for the direct effect of welfare participation on utility, a parameter to measure the disutility associated with welfare participation is included in the utility function. This model allows for the fact that not all eligible people are participating in welfare.

The results indicate that there is evidence of a significant disutility associated with welfare participation. From simulations, it is found that a change in the benefit withdrawal rate or the maximum benefit level does not seem to have a large effect on the labour supply of either adult.

1 Introduction

The effect that welfare payments have on labour supply or labour force participation is a research topic that has attracted ample attention in the overseas literature, but so far there has been relatively little research on labour supply in Australia. The main aim of this paper is to set up a model in which the effect of unemployment benefits on labour supply can be adequately assessed using Australian data.

The emphasis of the basic framework is on the separation of income into different categories and on a correct representation of net income at all levels of gross income, taking taxes and benefit reduction into account. This results in a highly nonlinear and non-convex budget constraint.

Although many papers have been written on the effects of different types of government benefit payments on labour supply, fewer papers have included in their analysis a possible negative side effect of receiving benefits[1]. One cause for this possible negative effect might be that welfare recipients feel some embarrassment because of the social stigma involved in their accepting public assistance, which might discourage such acceptance. Another cause for a negative effect might be transactional costs associated with the receipt of welfare payments. The purpose here is to test for the presence of a negative side effect in Australian data by estimating a simultaneous model of labour supply and welfare participation and allowing a direct effect from welfare participation on the utility level. If the negative effect of welfare participation is too large, eligible households may decide not to participate in welfare.

Section 2 briefly discusses the economic model. Section 3 describes the data. Section 4 contains the econometric details. The results are discussed in Section 5, and the conclusions are presented in Section 6.

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1 Examples of exceptions are Moffitt (1983), Ashenfelter (1983), Fraker and Moffitt (1988), Woittiez, Lindeboom and Theeuwes (1994), Charette and Meng (1994), Hagstrom (1996), Hoynes (1996).

2 The Economic Model

By setting up the model in the familiar neoclassical way, starting from utility maximisation under a budget constraint, a logical and consistent framework can be built to analyse labour supply (see for example Deaton and Muellbauer, 1980, or Killingsworth, 1983). We are interested in a two-adult household (with or without dependent children), where the adults can choose their labour supply and the household's participation in welfare to optimise its utility. A simple utility maximising model could look as follows:

$$\max U(x, lhh_1, lhh_2, d_W) \tag{1}$$

subject to:

$$T = lhh_1 + h_1$$

$$T = lhh_2 + h_2$$

$$x = \int_0^{h_1} g_1(t_1,h_2)dt_1 + \int_0^{h_2} g_2(h_1,t_2)dt_2 + n(y_1) + n(y_2) + n(B(hc))d^*_W$$

Or if the three restrictions are taken together, the budget constraint may be written:

$$\begin{aligned} x + \int_{T-lhh_1}^{T} g_1(t_1,T\text{-}lhh_2)dt_1 + \int_{T-lhh_2}^{T} g_2(T-lhh_1,t_2)dt_2 = \\ \int_0^T g_1(t_1,T)dt_1 + \int_0^T g_2(T,t_2)dt_2 + n(y_1) + n(y_2) + n(B(hc))d^*_W \end{aligned} \tag{2}$$

where:

$U(\ )$ is the utility function of a two-adult household,

lhh_1 and lhh_2 indicate the aggregate of leisure time and home production time per week of persons 1 and 2 respectively,

x indicates net income per week,

d_W indicates whether a household participates in welfare,

T is the total available time for each person in the household,

h_1 and h_2 are the hours of work of persons 1 and 2,

$g_1(,)$ and $g_2(,)$ are the marginal wages of persons 1 and 2,

y_1 and y_2 are the non-labour incomes of persons 1 and 2,

B(hc) is the amount of benefit a household is eligible for given household composition hc,

n( ) is the amount of income after the deduction of taxes,

$d_W{}^*$ indicates the inclination of the household to participate in welfare if eligible.

The combination of leisure, income and welfare participation that delivers the highest utility to the household is regarded as the optimal choice. It is expected that utility increases with an increase in leisure and income and that it decreases with an increase in welfare participation. The disutility caused by welfare participation can be explained either by the existence of a stigma associated with welfare participation or by administrative and/or other costs of applying for welfare. This disutility might completely or partly offset the utility associated with the extra income, possibly depending on the amount of extra income.

With regard to the assumption of free choice underlying this economic model, it should be noted that, in practice, voluntary non-workers often cannot be distinguished from involuntary non-workers. Neither is it known whether the observed labour supply is the optimal labour supply or, alternatively, whether people are restricted in their choice of number of hours worked by demand side factors. It would be interesting to analyse desired hours of work instead of actual hours of work or to allow for the restrictions in actual hours caused by the demand for labour. For the moment, actual hours are used and it is assumed that they are equal to the desired hours of work.

3 The Data

The ABS Income Distribution Survey 1986 has detailed income data for each person separately and for the household as a whole. This allows the budget constraint to keep its full complexity: a point of major importance given the main aim of our study. However, some problems were encountered with the data.

3.1 Data Problems

The data come from the unit record file of the ABS income distribution survey 1986. The data set is only available to us in two separate files. The major part comes from the regular file. This contains many background characteristics for all individual persons in the surveyed households who were 15 years or older at the time of the survey and detailed information on income received by each person. Even more important for this research is that the information on number of hours worked. In the regular file this has been aggregated into intervals of one to nine hours per week, 10 to 19 hours per week, 20 to 24 hours per week, 25 to 29 hours per week etc., until the last category of more than 50 hours per week. The ABS was approached for additional data on the exact number of hours worked and although the original information was no longer readily available (the survey was in 1986), they gave permission to copy the necessary file from one held at another university.

Each of the records in both files is identified by a unique identifier for each household, a family number, an income unit number and a person number. Unfortunately, the household identity numbers do not match, so these numbers cannot be used to connect the two files. However, there was some common information available in both data sources to connect the two files. Both files have some information on household composition and on the working hours of its members in their main and second jobs.

To find the matching records the records in each file were ordered firstly according to the number of records per household, secondly according to household identity number (to create the groups per household), thirdly according to hours worked in main, second and all jobs of the head of the household, and fourthly according to family number, income unit number and person number. In this way, the data were grouped in a similar way in both data files (these groups are called matching groups).

Households with a unique combination of the above variables and hours worked of the other household members can be exactly matched. After the matching procedure is finished about 17 per cent (3793 out of 17 714) of the individual records are exactly matched.

For the analyses in this study, we only want to use households that contain at most one income unit and consist of a head and a partner with or without dependants. The data are rearranged into records per income unit instead of individual records. Starting from a total data set of 17 714 individual records, 4378 income units remain to be analysed after the above selection and aggregation. From these income units, 271 were exact matches; thus, the number of exact matches dropped from about 17 per cent to 6.2 per cent.

This seems a dramatic drop. However, there are some explanations. The first one is that the income unit of interest is one of the most common and therefore is probably more difficult to match exactly. The second explanation is that we changed from records per individual to records per income unit. Income units with more records were easier to match, but all these separate individual records were transformed into just one income unit record. This causes the percentage of exactly matched individuals to be higher than the percentage of exactly matched income units.

Since in this case *exact* additional information is available for only a small percentage (6.2 per cent) of the income units, we would like to use the exact information together with the information available for non-exact matches to make optimal use of the data. An adaptation of the EM algorithm has been developed which is used here to utilise the information from both files[2].

2 For a brief description, see the appendix. A full description and derivation is given in Kalb (1997).

3.2 Selection Criteria for Inclusion in the Analyses

So far, one selection criterion has been introduced resulting in a total sample of 4378 households. This first selection has created a population of two-adult households for which it seems reasonable to adopt the assumption that the household takes joint decisions and maximises a single utility function according to a common vision of the household's welfare.

This is the only selection where matching groups are included or excluded as a whole. The 4378 cases selected are used to create a file with matching group numbers and corresponding hours worked in main and second job for both Person 1 and Person 2 in the household. This is used later as the data set from which possible 'hours worked' for the observations in the main data set can be chosen, according to their matching group numbers.

In this section, additional selection criteria are discussed. These selections can only be performed on the main data set and thus records from some of the matching groups are excluded in the main data set, but not in the additional data set.

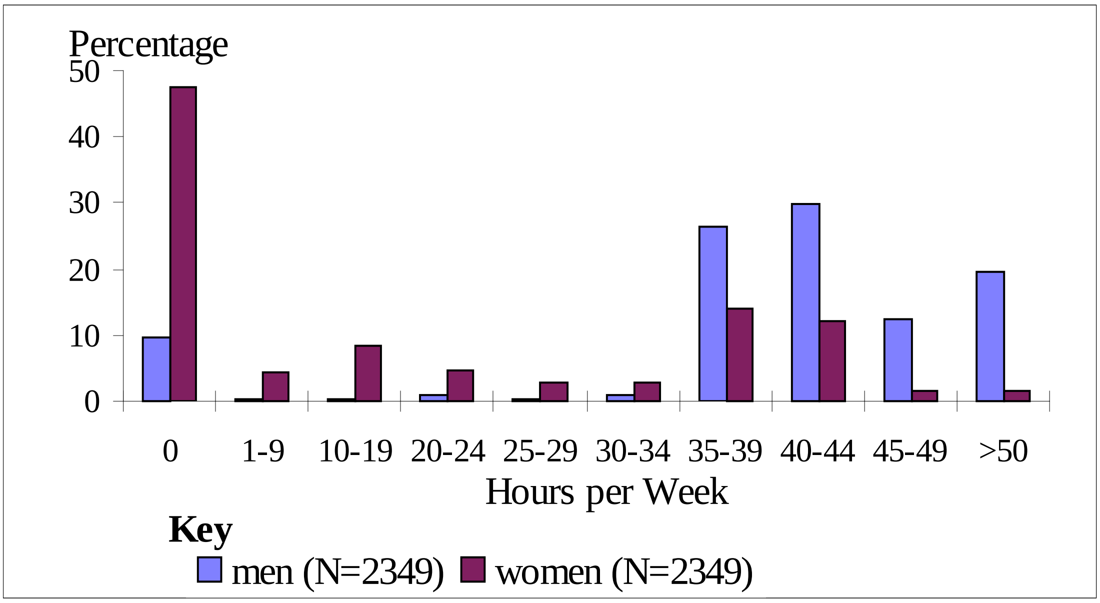
- People of an age to be eligible for government paid age pensions are excluded. They are expected to behave differently from younger people.
- For the same reason of substantial differences, the self-employed are also excluded.
- All people temporarily or permanently unable to work because of illness or disability are excluded from the analysis.
- People receiving a (military) service pension are not included, since these pensions are paid instead of age pension or in cases of disability.
- People who care for family members including a handicapped child and receive benefits for doing so, as well as people receiving a group of benefits not named anywhere else are also excluded from the analysis.

- Finally, a few households detected in the data set seemed not to be two-adult households (where resources are shared between the two adults).

After the above selection process, a data set of 2349 households is left.

Figure 1 gives an overview of the sample frequency distribution of working hours for people of working age[3] who were not self-employed. The difference between males and females is obvious and as expected. Relatively more women work part time and more men work full time (especially over 45 hours per week).

Figure 1: Labour Supply of Males and Females



Missing values or outliers (which may be measurement errors) result in the deletion of a few additional households in subsequent analyses. First, some values for wage income seem unrealistically small when compared to the corresponding hours worked. In Australia there is no Federal or state minimum wage covering all employees. Each award has its own minimum wage. Therefore, across states, occupations and industries,

3 Working age people are those people who are not eligible for age pension, so men younger than 65 years and women younger than 60 years are those included.

minimum wage levels vary. The lowest value found[4], was the minimum weekly wage rate for adults in Federal awards for Brisbane of $164.30 per week (see *Queensland Yearbook 1988*, ABS, 1989b). Assuming the standard hours per week to be 40 (which might be a slight overestimate), this translates into a minimum hourly wage rate of $4.11 per hour. Therefore in the estimation of the wage equation all persons earning less than $4 per hour are excluded (the same selection is used to estimate both the wage equation and the labour supply equation). Second, all households who had a weekly income of less than $100 are also excluded. When this happens, some observations may be wrongly excluded as it is possible that some households may live off their savings temporarily. In the final labour supply analysis 2280 cases remain. Table 1 gives summary statistics of the variables which are used in the analysis.

The background characteristics used to specify preferences in the utility function are listed here.

Age, which is known in categorised form only. The midpoint values of each category are used. Younger and older persons are expected to have a higher preference for leisure.

Education is divided into the following categories:

- never been to school or left school before the age of 14
- did not finish secondary school, left school before the age of 16
- did not finish secondary school, left school at 16 years or older
- finished secondary school or obtained secondary qualification since leaving school
- obtained a trade certificate
- obtained other certificate or diploma
- obtained bachelor degree or higher qualification
- obtained other qualification

4 Based on checking the ‘Award Rates of Pay Indexes’ (ABS, 1988) and ABS Yearbooks.

Table 1: Summary Statistics (N=2280)

Variable	Mean	Standard Deviation
Number of children	1.37	1.25
Age of youngest dependent child below 15 (if present)	4.95	4.33
Unemployment benefits	8.96	40.88
Mortgage debt	14 138.9	19 062.71
Non-labour income of men	22.20	121.64
Non-labour income of women	12.36	52.31
Wage income of men	451.79	243.20
Wage income of women	147.92	179.70
All income of men	478.69	253.58
All income of women	170.71	181.11
Age of men	37.50	10.10
Age of women	34.90	9.70
Number of weeks worked last year by men	47.36	13.13
Number of weeks worked last year by women	26.16	23.72

Variable	Percentage
State of residence	
• New South Wales	24.1
• Victoria	20.2
• Queensland	16.8
• South Australia	12.8
• Western Australia	14.2
• Tasmania	7.5
• Territories	4.5
Participation in welfare	5.0
Eligibility for welfare	6.7
Ethnicity men	3.2
Ethnicity women	3.9
Men who worked more than 35 weeks in last year	90.4
Women who worked more than 35 weeks in last year	47.3
Education of men	
• No school/ left before 14 years of age	3.5
• Left school at age 14 or 15	18.0
• Left school older than 15	11.7
• Secondary school/qualification	11.8
• Trade certificate (no field)	2.5
• Trade certificate (technical)	23.2
• Trade certificate (miscellaneous)	4.1
• Other certificate/diploma (business, commerce)	4.4
• Other certificate/diploma (education)	1.5
• Other certificate/diploma (medical)	0.8

Table 1: Summary Statistics (N=2280) (continued)

Variable	Percentage
• Other certificate/diploma (technology)	5.0
• Other certificate/diploma (social sciences, arts)	0.4
• Bachelor or higher (business, commerce)	2.9
• Bachelor or higher (education)	2.0
• Bachelor or higher (medical)	0.5
• Bachelor or higher (technology)	5.1
• Bachelor or higher (social sciences, arts)	1.7
• Other qualification	0.9
Education of women	
• No school/ left before 14 years of age	3.2
• Left school at age 14 or 15	31.8
• Left school older than 15	17.0
• Secondary school/qualification	11.4
• Trade certificate (no field)	0.9
• Trade certificate (technical)	0.1
• Trade certificate (miscellaneous)	2.9
• Other certificate/diploma (business, commerce)	10.4
• Other certificate/diploma (education)	4.9
• Other certificate/diploma (medical)	7.0
• Other certificate/diploma (technology)	0.6
• Other certificate/diploma (social sciences, arts)	0.9
• Bachelor or higher (business, commerce)	0.7
• Bachelor or higher (education)	3.0
• Bachelor or higher (medical)	0.4
• Bachelor or higher (technology)	1.1
• Bachelor or higher (social sciences, arts)	2.2
• Other qualification	1.6

Education is expected to increase the preference for work, because time and money have been invested in human capital. Apart from the financial rewards, one would expect a high-skill job to be more interesting than a low-skill job and hence more desirable.

The *number of dependent children* in each household is calculated by adding the number of dependent children from 0 to 20 years old. This variable is expected to be especially important for the female adult in the households. Children are likely to increase the value of time at home, which is reflected in a higher preference for leisure in the model.

The survey records the *age of the youngest dependent child under 15 years of age* in the household. The effect of dependent children in the household is likely to be even bigger when young children are present.

The *value of the outstanding mortgage* is likely to be simultaneously determined with labour supply and thus an endogenous variable itself. Our cross-sectional data does not allow us to specify a model that would take this into account. Therefore, it is modelled as having an effect on preferences. However, it should be realised that the decision to buy a house and take out a mortgage is probably influenced by labour supply now and the prospects of labour supply in the future.

Variables expected to be relevant to the wage rate are described here.

Age and *Age*^{2}, because age reflects the experience people are likely to have had in the labour market. If the interest were in the separate effects of schooling and experience, this would not be an adequate specification (Mincer, 1974; Rosenzweig, 1976). The parameters would not reflect the effects of interest, as more schooling would mean that someone of the same age has had less work experience. However, here the goal is to predict a wage rate for the non-workers and the separate effects are not so important.

Education, which is expected to determine the wage level to a great extent.

The *field* in which the highest educational qualification is attained is only available for those people who have qualifications beyond secondary school. The categories used here are:

- *administrators, lawyers, business professionals:* a degree or diploma in administration (including secretarial work), business, commerce, law
- *professionals in education:* a degree or diploma in education or teacher training
- *medical professionals and para-professionals:* a degree or diploma in the medical field (including nursing and para-medics)

- *technologists and technicians:* a degree or diploma in science, engineering, architecture, agriculture, forestry veterinary science, transport, communication or a certificate in metal, building, electrical, wood and furniture or mechanical and automotive

- *social scientists, social workers, graduates in the humanities:* a degree or diploma in social sciences, arts and humanities

- *miscellaneous:* a certificate in service, food and drink, printing and allied, and footwear, clothing and textiles.

A combined variable using information from the highest education level and from the field of qualification is used in the analysis. Wages can differ widely over the different fields of education.

A proxy for *ethnicity* is generated by creating a dummy variable that takes the value 1 for all people who arrived in Australia after 1980 from origins other than the United Kingdom. This variable is intended to identify recent immigrants who possibly have difficulties with the language and/or culture of Australia. These difficulties might have an adverse effect on the wage rate.

Recent work experience is represented by a dummy variable, which takes the value of 1 if the person has been employed during more than 35 weeks in the previous year. In this way, people just starting a career or people with a break in their career can be identified. People with up-to-date skills and experience are likely to receive higher pay.

State of residence indicates the state or territory. Unfortunately, the Northern Territory and the Australian Capital Territory are categorised as one group, which is a disadvantage for the estimation of the wage equation, as the job markets in these two regions differ considerably.

Other important variables in the analysis are noted below.

Non-labour income (excluding the unemployment benefit) is constructed by adding all income from investments, rents and dividends to superannuation payments, compensation payments and other regular income (excluding income from the first homebuyer scheme).

The *wage rate* cannot be exactly determined in most cases. Only *weekly income from wage and salary* is known which has to be divided by the unknown exact number of 'hours worked' to get the wage rate. The wage rate depends on the connections made between the main and the additional data set.

Participation in welfare payments is represented by a dummy variable, which is 1 when the household receives unemployment benefits.

The last variable is *eligibility for welfare payments*. This variable has been calculated using household composition and household income. This variable is an approximation as not *all* the details necessary to determine eligibility are available. However, the main determining variables are available to us. It appears that a few more families are eligible than those who have applied for the benefits.

4 Econometric Specification

In Section 2 an economic model was introduced that serves as a starting point for specifying an econometric model. Computational restrictions and available data, however, limit the econometric models that might be successfully estimated. In the following sections, possible options are discussed.

4.1 Specification of a Labour Supply and Welfare Participation Model

Dealing with a Nonlinear and Non-convex Budget Constraint

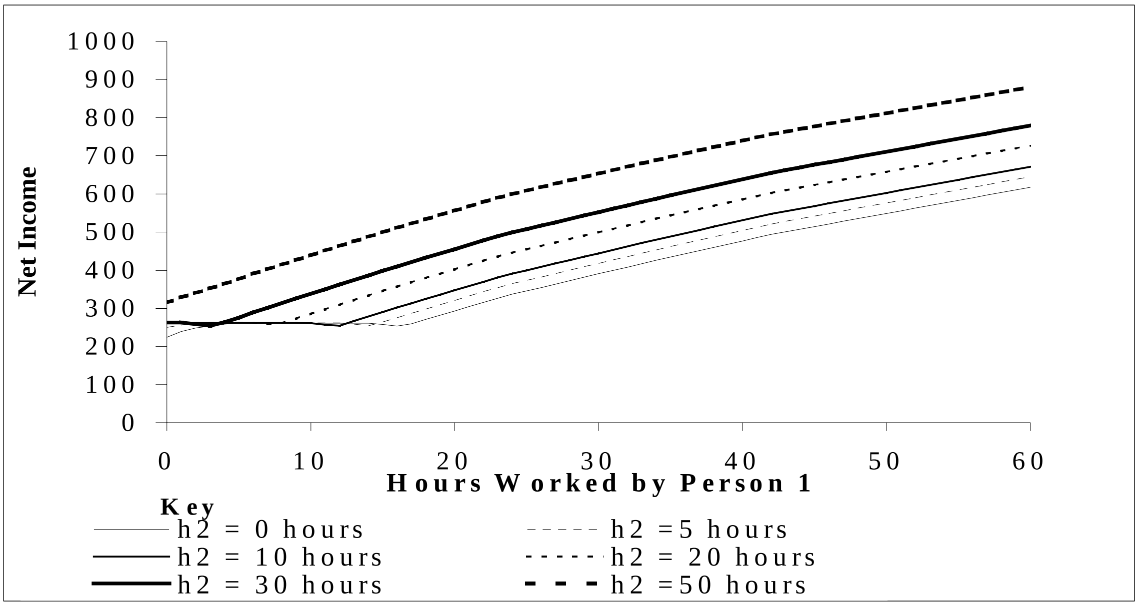
Including taxes and benefits for two persons in the budget constraint produces a highly nonlinear constraint. Looking at the benefit and tax regimes of 1986[5] leads us to expect many kinks in the budget constraint. Since we prefer to keep the representation of taxes and benefits as close to reality as possible, a complex budget constraint cannot be avoided. To illustrate the possible implications of the tax and benefit rates of 1986 for the shape of a budget constraint, Figure 2 takes a hypothetical household

5 For an overview of the basic rules, see the appendix.

consisting of two adults and two children under 16 years, where Person 1 has a market wage of $16.00 per hour and Person 2 has a market wage of $7.00 per hour.

In Figure 2 the working hours of Person 2 are fixed and net income is calculated over the number of hours worked by Person 1. It can be seen that in the lower regions of income the marginal wage rate at a certain number of hours for Person 1 also depends on the number of hours supplied by Person 2.

Figure 2: Net Household Income when Hours of Person 2 are Fixed and Wage Rates are $16.00 for Person 1 and $7.00 for Person 2



It is clear that the lines that represent the budget constraint are nonlinear. In the case where one only considers one potential worker at a time, the labour supply estimation can already be quite complex, when a realistic representation of taxes and benefits is taken into account[6]. In the case where households with two potential workers are analysed, subject to their joint budget constraint, which includes both taxes and benefits, the complexity is even greater.

6 See e.g. Burtless and Hausman (1978), Hausman (1979), Hausman (1985) or Moffitt (1986) for a continuous labour supply approach with a nonlinear (non-convex) budget constraint.

Restricting the number of possible working hours, to a limited set of discrete values (as is done by many authors facing the same problem), appears an attractive solution. For this limited set of hours, one can calculate the level of utility that each possible combination of hours would generate, according to the specified utility function. An additional advantage of the discrete approach is that coherency does not have to be imposed before using maximum likelihood methods to estimate the model, as would be necessary in the case of continuous labour supply for some utility functions (see Van Soest, Kapteyn and Kooreman, 1993).

Instead of being defined on a continuous set of working hours, $h_1, h_2 \in [0,T]$, in the discrete choice case the budget constraint is defined on a discrete set of points on the interval [0,T]:
$h_1 \in A = \{0, dh_{11}, dh_{12},..., dh_{1m}\}$ and $h_2 \in B = \{0, dh_{21}, dh_{22},..., dh_{2k}\}$
Using these sets, the net income $x(h_1, h_2)$ is calculated for all $(m+1)\times(k+1)$ combinations of h_1 and h_2 (where m+1 is the number of discrete points for h_1 and k+1 is the number of discrete points for h_2). By increasing the number of different hours in the choice set, the quality of the representation improves. However, the computational load also increases, so a compromise between quality and computational feasibility is necessary. In addition to this discrete choice of hours, participation in welfare is a choice variable as well. This choice variable can only take two different values: one for participation and zero for non-participation, so $d_W \in C = \{0,1\}$. For all working hours where households are still eligible for a benefit, an additional value for the net income $x(h_1, h_2, d_W)$ has to be calculated. So net income x is dependent on labour supply and wage rates of both adults, on non-labour income, on household composition and on participation in benefits (d_W). Wage rates, non-labour income and household composition are exogenous in this model. The model becomes:

$$\max U(x, lhh_1, lhh_2, d_W) \tag{3}$$

subject to:

$$(x, lhh_1, lhh_2, d_W) \in BC(w_1, w_2, y_1, y_2, hc) \tag{4}$$

where:

$$BC(w_1, w_2, y_1, y_2, hc) = \{(x, T-h_1, T-h_2, d_W); (h_1, h_2, d_W) \in \mathcal{A} \times \mathcal{B} \times \mathcal{C}$$
$$\text{and } x = w_1 h_1 + w_2 h_2 + y_1 + y_2 + B(hc, w_1 h_1 + w_2 h_2 + y_1 + y_2) d_W -$$
$$\tau(B.d_W, w_1 h_1 + y_1, w_2 h_2 + y_2, hc)\}$$

where:

w_1 and w_2 are the gross wage rates of Person 1 and Person 2,
BC is the set of discrete points h_1, h_2 and d_W plus the net income x which is calculated for each of these points,
$\mathcal{A}$, $\mathcal{B}$ and $\mathcal{C}$ are the sets of discrete points from which values can be chosen for h_1, h_2 and d_W,
B is the amount of benefit, for which the household is eligible, given household composition and income,
τ is the tax function that indicates the amount of tax to be paid, given total gross income.

In the discrete choice model, it is not necessary to know the marginal wage rates. Therefore, the budget constraint can be written as total gross income minus the tax that has to be paid on this total income. The tax and benefit rules are explained in the appendix.

Assuming that the observed combination of hours is the optimal combination as perceived by the household, a likelihood function can be formed. The contribution of each household to the likelihood function is the probability that the observed hours indeed result in an optimal utility for the household of interest when compared with all other possible choices for hours. Thus, the elementary part of the likelihood function looks as follows:

$$\Pr(U(x((lhh_1, lhh_2, d_W)_r), (lhh_1, lhh_2, d_W)_r, \varepsilon_r) \geq$$
$$U(x((lhh_1, lhh_2, d_W)_s), (lhh_1, lhh_2, d_W)_s, \varepsilon_s) \text{ for all s}) \qquad (5)$$

where:

r stands for the combination h_1, h_2 and d_W that is observed,

s stands for all (k+1)×(m+1) other possible combinations that can be made, given the discrete choice sets for hours worked and participation in welfare, ε_r and ε_s represent error terms.

Adding an error term to the utility function prevents contributions to the likelihood in any data point from becoming zero. It allows for optimisation errors made by the household. Alternatively, the error term can sometimes be interpreted as unobserved specific utility components. By choosing different functional forms for this error term (e.g. normal or type I extreme value), a different discrete choice model results (e.g. a multinomial probit or logit model). After specifying a functional form for utility, parameters of this model can be estimated by maximum likelihood.

The option of receiving welfare is only available when certain income requirements are fulfilled. This means that in most cases the household can only receive welfare payments when the number of working hours is low. The participation in welfare according to the model above is assumed to be a voluntary decision together with the number of hours worked. Therefore, the case where the number of hours worked is rationed is not covered by this model.

We have to keep in mind that the choice of discrete hours and the categorisation of actual hours into predetermined groups has implications for the theoretical eligibility for welfare. To illustrate this issue, let us consider a household with one non-participant and one part-time worker, who works seven hours per week and let us assume that the household ‘chooses’ to participate in welfare. Using three discrete points to represent the labour supply of each adult in the household, we can distinguish, for example, whether someone is not working, working part time or working full time. The households can then be categorised as non-participating (neither of the two adults work), as full-time/ non-participating (for a one income household, where Person 1 works full time), as full-time/part-time (where Person 1 works full time and Person 2 works part time), etcetera. Suppose this household were categorised as a part-time/non-participating household and the part-time discretised number of hours was 20 hours. It is plausible to assume that the household at seven hours of work is eligible for welfare benefits, while at the same wage rate, but working 20 hours this same household might no longer be eligible. The reverse might occur as well, when for example a household with one person working 30 hours is categorised as a part-time/non-participating household and, according to the model, has a choice of participating in welfare which does not exist in reality. In these cases, the data cannot be reconciled with the chosen discretisation of the model.

Researchers mainly interested in labour supply behaviour and less interested in welfare participation, can choose the discrete points of labour supply in their model to best represent the actual labour supply. To assess the possible adverse impact of receiving welfare payments, the discrete points chosen should represent as accurately as possible eligibility for welfare, as well. Other researchers for whom welfare participation is also an issue of interest and who use a discrete labour supply model, do not appear to explicitly consider this potential problem of reconciling the data with the chosen discretisation.

People who only work a few hours and earn an income that makes them just eligible or just not eligible for welfare are of particular interest when studying the impact of benefits on labour supply. They are probably the people who would not lose much by not working and receiving full benefits, but nevertheless they still work. Also, some of them might even be eligible for benefits but are not applying for them. This is valuable information with respect to the analysis of the effect of benefit payments on labour supply. Therefore, some careful thought should be given to the way in which labour supply is discretised. Before choosing our discrete labour supply points, different values for the discrete points are compared, especially the ones representing part-time workers. Eligibility can be calculated at the determined labour supply points for all observations and these can then be compared to the actual values. The discrete labour supply points considered are chosen from an area of labour supply where many workers are located and that adequately represent the actual eligibility for welfare.

Specification of the Utility Function

To operationalise the discrete choice model, it is necessary to specify a utility function. For the sake of convenience the one used here is the translog specification (following Van Soest, 1995), to which a dummy term is added for participation in welfare[7]. This is in line with the approach of other papers on labour supply and welfare participation, in which it is also assumed that the disutility from welfare participation is separable from the utility from leisure and goods. The utility derived from leisure, income and welfare participation can be written as:

$$
\begin{aligned}
U(x,h_1,h_2,d_W) = {} & \beta_x \ln(x) + \beta_1 \ln(80-h_1) + \beta_2 \ln(80-h_2) + \alpha_{xx}\big(\ln(x)\big)^2 + \\
& \alpha_{11}\big(\ln(80-h_1)\big)^2 + \alpha_{22}\big(\ln(80-h_2)\big)^2 + 2\alpha_{x1}\ln(x)\ln(80-h_1) \\
& + 2\alpha_{x2}\ln(x)\ln(80-h_2) + 2\alpha_{12}\ln(80-h_1)\ln(80-h_2) - \varphi d_W
\end{aligned}
\qquad (6)
$$

where $\alpha_{..}$, $\beta_{.}$, and φ are parameters that have to be estimated.

This utility function has a simple form, and heterogeneity of preferences is easy to include. Here the total endowment of time (T) is chosen to be equal to 80 hours per week. A disadvantage of this functional form is that utility is not automatically quasi-concave. However, if the two conditions outlined below are fulfilled at a data point, then U is quasi-concave at that point (Van Soest, 1995).

First, U has to increase with x:

$$
2(\alpha_{xx}\ln(x) + \alpha_{1x}\ln(80-h_1) + \alpha_{2x}\ln(80-h_2)) + \beta_x > 0 \qquad (7)
$$

and second, the matrix of second order derivatives of income x with respect to leisure of person 1 and person 2 (HX) has to be positive definite:

$$
HX = -U_x^{-1} \left| \begin{matrix} x_{lhh_1} & 1 & 0 \\ x_{lhh_2} & 0 & 1 \end{matrix} \right| HU \begin{bmatrix} x_{lhh_1} & x_{lhh_2} \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad (8)
$$

where:

U_x is the partial derivative of U with respect to income x;

---

7 Only participation and non-participation are distinguished. The amount of participation, as could be expressed by measuring the value of the benefit received, is not taken into consideration as far as its direct effect on the utility is concerned.

HU is the matrix of second order partial derivatives of U;

$x_{lhh_1} = -\frac{U_{lhh_1}}{U_x}$, the marginal rate of substitution of leisure of person 1 with income x;

x_{lhh_2} is the same as above, but for leisure of person 2;

U_{lhh_1} is the partial derivative of U with respect to leisure of person 1;

U_{lhh_2} is the partial derivative of U with respect to leisure of person 2.

In a model with continuous hours of labour supply, these conditions would have had to be imposed a priori to guarantee coherency, as has been mentioned earlier. This would have complicated the maximum likelihood estimation. In the approach taken here, these two conditions can be tested at all data points after estimation of the parameters.

To account for differences in preferences between households, the parameters β, α and φ can be made dependent on some household characteristics. For the moment it is assumed that no heterogeneity is present in the preferences and only β_1 and β_2 depend on personal and household characteristics (see section 3.2). Simple linear specifications are chosen.

In the present study, where the data demand an additional complexity in the estimation procedure, we decided to take a relatively simple approach. Choosing an extreme value specification for the error term in (5) results in a multinomial logit model (see Maddala, 1983) where the relatively simple likelihood contribution looks as follows:

$$L = \frac{\exp(U_{i'j'k'})}{\sum_{i,j,k} \exp(U_{ijk})} \tag{9}$$

where:

i indicates the labour market status of Person 1;

j indicates the labour market status of Person 2;

k indicates welfare participation. k $\in$ {0,1}, where 0 stands for non-participation and 1 for participation in welfare.

U_{ijk} is the level of utility derived from the state where person 1 has labour market status i, person 2 has labour market status j and the household has welfare participation k.

This expression denotes the probability that the utility in the observed situation is higher than the utility in any other situation. This specification is also chosen by Van Soest (1995), who has successfully specified 36 different discrete points. This means that at least four labour supply points for both men and women could be included. This would help to represent eligible and nearly eligible households correctly. Due to the independence of irrelevant alternatives assumption underlying the multinomial logit model, the error terms cannot be interpreted as reflecting random preferences, but only as optimisation errors. Random preferences can be incorporated in the model by adding random components to the preference parameters. Van Soest shows that it is relatively simple to include heterogeneity in the preferences or to integrate the likelihood function over a distribution of wages by using simulation techniques. In practice, it would mean a larger number of parameters to estimate and a more complicated likelihood function to maximise. Therefore, these extensions of the model are left for future research.

In the present case, where the number of hours are not exactly observed, the contribution to the likelihood function of some observations will change. Households with two non-participants in the labour force are not affected by the scrambling of the data, so the contribution to the likelihood remains the same for this group of people. For all households where the hours worked are not exactly known an expected likelihood contribution is used, as explained in Kalb (1997). The expectation is taken with respect to the actual hours. The basic unit of observation no longer is the individual household but all the households that belong to the same matching group. The contribution to the log likelihood for a matching group with N possible observations of actual hours for Persons 1 and 2 ($A = \{(H_{11}, H_{21}), (H_{12}, H_{22}), ..., (H_{1N}, H_{2N})\}$) and the M possible observations, to which these hours should be matched, is:

$$
\begin{aligned}
Q(\theta,\theta^{q};A) = \sum_{m=1}^{N}\sum_{\substack{n=1\\ n\neq m}}^{N}\cdots\sum_{\substack{p=1\\ p\neq n,m}}^{N} \Bigg\{ \Bigg[& U_{i'j'k'}(H_{1m},H_{2m}|X_1,\theta) - \\
& \ln\left| \sum_{i,j,k} \exp\Big(U_{ijk}(H_{1m},H_{2m}|X_1,\theta)\Big) \right| \Bigg] + \ldots . + \\
& \left[U_{i'j'k'}(H_{1p},H_{2p}|X_M,\theta) - \ln\left[\sum_{i,j,k} \exp\Big(U_{ijk}(H_{1p},H_{2p}|X_M,\theta)\Big) \right] \right] \Bigg\} \bullet
\end{aligned}
$$

$$
\frac{\dfrac{\exp\Big(U_{i'j'k'}(H_{1m},H_{2m}|X_1,\theta^{q})\Big)}{\sum_{i,j,k}\exp\Big(U_{ijk}(H_{1m},H_{2m}|X_1,\theta^{q})\Big)}\cdots\dfrac{\exp\Big(U_{i'j'k'}(H_{1p},H_{2p}|X_M,\theta^{q})\Big)}{\sum_{i,j,k}\exp\Big(U_{ijk}H_{1p},H_{2p}|X_M,\theta^{q})\Big)}}{\sum_{m=1}^{N}\sum_{\substack{n=1\\ n\neq m}}^{N}\cdots\sum_{\substack{p=1\\ p\neq n,m}}^{N}\dfrac{\exp\Big(U_{i'j'k}{}'(H_{1m},H_{2m}|X_1,\theta^{q})\Big)}{\sum_{i,j,k}\exp\Big(U_{ijk}(H_{1m},H_{2m}|X_1,\theta^{q})\Big)}\cdots\dfrac{\exp\Big(U_{i'j'k'}(H_{1p},H_{2p}|X_M,\theta^{q})\Big)}{\sum_{i,j,k}\exp\Big(U_{ijk}(H_{1p},H_{2p}|X_M,\theta^{q})\Big)}} \tag{10}
$$

This is the expected log likelihood $Q(\theta,\theta^{q};A)$ as used in the EM algorithm[8], where θ is the parameter vector to be estimated and θ^{q} is the optimal parameter vector from the previous maximisation step. X contains all personal and household characteristics and the welfare participation indicator, which are known exactly for each observation. Q is maximised with respect to θ. The estimated vector θ^{q+1} is then used to calculate the expected log likelihood function $Q(\theta,\theta^{q+1};A)$ in the next iteration step. Iterations are stopped when θ^{q} and θ^{q+1} are equal, up to a predetermined degree of precision.

Expression (10) is hard to calculate exactly when the matching groups contain many observations. Therefore, the expected value is approximated (as in Kalb, 1997), by simulating values from an appropriate distribution with the help of importance sampling (see Kloek and Van Dijk, 1978; Van Dijk and Kloek, 1980).

---

8 See Dempster, Laird and Rubin (1977) or see the appendix for a short exposition.

4.2 Unobserved and Scrambled Wages

Like all other researchers in this area, we have to deal with unobserved market wages for people who are not working. In addition, the problem of not exactly observing actual working hours is transferred to wage rates as well, since wage rates are calculated by dividing weekly income from wages and salaries by hours worked per week.

The best way to deal with unobserved wages is to incorporate them into the likelihood function and estimate wages and labour supply simultaneously. However, this is computationally difficult and it is not attempted often[9]. Because in the present study additional complications play a role, the simplest solution is implemented. The wage equation is estimated separately and estimated wages are used as if they represent the true values of the unobserved wages. The drawback of this approach is that it assumes labour supply to be linear in the logarithm of the wage rate and it ignores the simultaneity of wages and labour supply. Given the problems that already exist when estimating a labour supply model using the available data, it seems reasonable to leave this problem to one side (at least for the moment). In future research the error term of the wage equation might be included and integrated out of the likelihood to account for the often serious inaccuracy of the estimated wage rates. To correct for a possible selection bias as a result of only observing wage rates for workers the Heckman correction term for participation is included in the wage equation (Heckman, 1979).

Once all the parameters of the wage equation are estimated, estimated wage rates for the non-participants can be generated using the wage equation with the estimated correction term for the non-participants.

5 Results from the Estimation of the Labour Supply Model

In this section, the focus is on the labour supply equation; the results from the participation and wage equations are presented in the Appendix.

9 Exceptions are, for example, Fraker and Moffitt (1988), Gerfin (1993) and Murray (1996).

Labour supply and welfare participation are estimated using imputed wage values for the non-workers as described in the previous section.

In principle, the data set used here contains desired hours of labour supply. Unfortunately, as with actual hours worked, desired hours are only known for each group and not for each individual. The variation within each matching group in possible values for desired hours of work is, however, much larger than for actual hours of work. This means that estimation is more difficult using desired hours rather than actual hours, possibly taking the work outside the range of what is computationally feasible. For this reason, the estimations are performed with the actual working hours of both persons as two of the endogenous variables.

For the estimation of labour supply an additional five records are lost, because the observation on the household's welfare participation and their calculated eligibility are contradictory. The remaining data set consists of 2275 households. The additional data set, from which the values of working hours are chosen, consists of 4141 records in 251 matching groups. The maximum size of the matching groups in the main data set is 273 records and 970 records in the additional data set. The maximum number of different values to choose from is 43.

The adapted EM algorithm is necessary in order to estimate the specified labour supply model. Computer power restricts the accurateness of the results. The time needed to calculate each term in the log likelihood function constrains the number of random values that can realistically be drawn to obtain an approximation of the expected log likelihood. However, the fluctuation between each iteration in the value of estimates of the parameters is normally below five per cent of its value after the approximate optimum is reached. Only for two parameters is it in the range of 12 to 20 per cent. The fluctuation in each parameter is at all times much smaller than the relevant standard deviation of the parameter.

5.1 Discussion of the Results

Table 2 gives the parameter estimates of the translog specification of the utility function for different numbers of discrete labour supply points. The labour supply points and the categorisation of the actual hours to

Table 2: Estimated Parameters of the Labour Supply Model

	Model A[(a)]		Model B[(b)]	
	Estimated coefficient	t-ratio	Estimated coefficient	t-ratio
β_X (income)	18.4590	5.208	16.7588	4.920
β_1 (leisure person 1)				
Constant	2.1894	0.367	-2.3221	0.429
Number of children	-0.4424	4.478	-0.3915	4.279
Age of youngest child				
• 0 - 5	0.4555	1.602	0.1946	0.745
• 6 - 12	0.4199	1.388	0.1568	0.569
Age man	-2.7603	3.658	-1.8822	2.797
Age^2 man	0.4313	4.598	0.3047	3.658
Mortgage/10 000	-0.1360	2.770	-0.1293	2.848
Education men (low)[(c)]				
• medium	0.0820	0.405	0.0763	0.418
• high	-0.8305	3.184	-0.6696	2.799
Education women (low)				
• medium	-0.4343	1.705	-0.3571	1.531
• high	-0.8969	4.235	-0.6631	3.406
β_2 (leisure person 2):				
Constant	58.5853	9.113	32.8757	5.355
Number of children	0.1922	1.398	0.3181	2.360
Age youngest child				
• 0 - 5	5.0157	13.817	4.8096	13.345
• 6 - 12	1.8439	5.196	1.3497	4.009
Age woman	-0.3870	0.408	-0.0653	0.074
Age^2 woman	0.1906	1.526	0.1290	1.108
Mortgage/10 000	-0.1875	3.613	-0.1856	3.827
Education woman (low)				
• medium	-0.3889	1.311	-0.3214	1.153
• high	-0.2794	1.139	-0.6289	2.746
Education man (low)				
• medium	0.2979	1.224	0.3298	1.438
• high	0.8324	2.790	0.7905	2.826
α_{xx}	2.2219	21.406	1.8251	18.070
α_{11}	-0.0946	0.282	0.3516	1.088
α_{22}	-1.1256	2.967	1.1509	3.160
α_{1x}	0.4450	1.900	0.2916	1.358
α_{2x}	-3.6909	14.147	-3.1508	12.469
α_{12}	0.9023	3.861	0.7815	3.678
φ (stigma effect)	5.1199	18.136	4.2928	16.422
LogL	3640.93		6518.36	
LogL0	3963.29		6834.06	

Notes:
a) Four discrete points of labour supply are distinguished for each person: 0 hours for non-participants, 20 hours for people working from 1 to 29 hours, 40 hours for people working from 30 to 49 hours and 55 hours for people working more than 49 hours.
b) Seven discrete points of labour supply are distinguished for each person: 0 hours for non-participants, 5 hours for people working from 1 to 9 hours, 15 hours for people working from 10 to 19 hours, 25 hours for people working from 20 to 30 hours, 35 hours for people working from 30 to 40 hours, 45 hours for people working from 40 to 50 hours and 55 hours for people working more than 49 hours.
c) Education levels are divided into: *low* for not finishing secondary school or not having any secondary qualifications, *medium* for finishing secondary school or having any secondary qualification/trade certificate and *high* for another certificate or diploma or for having a bachelor's degree or higher.

translate continuous hours to discrete points are chosen in such a way that for each observation the actual labour supply point can be unambiguously determined. All observations on actual working hours in a matching group are translated to the same discrete point. The model has been estimated with four and with seven labour supply points. In the specification with fewer points the emphasis is on the higher number of hours worked.

We looked at the number of cases for each specification in which the discretisation of labour supply caused eligibility for welfare to be incorrect. Since our data set does not have the exact labour supply for most households, different outcomes are possible depending on the value of labour supply that is chosen within the possibilities of the appropriate matching group. Each possible outcome is weighted equally within the matching group and the weights of all outcomes add up to one for each household.

In the categorisation with four points[10], it is found that the model indicates 23 households[11] as eligible who are not eligible when the full information is used. Vice versa, there are 30 households that are eligible according to the full information, but using the model, it is found that they are not eligible. An increase to seven points results in 23 households wrongly indicated as eligible by the model and 27 households wrongly indicated as ineligible.

Every possible value counts in the above comparison between eligibility according to the model and actual eligibility, but some of the possible values are unlikely to be the correct value for the household. Thus, the discrepancies between eligibility in the model and actual eligibility may be partly caused by the non-exact observation of working hours.

10 The exact categorisation of the working hours can be found in the footnotes below the table.

11 The calculated numbers have been rounded to the nearest integer.

Even though it seems, in theory, important to have a relatively large number of labour supply points[12], in this case it does not make much difference for a correct representation of welfare participation whether four or seven points are chosen to represent the actual labour supply. A larger number of labour supply points might become more important if the data set included a larger number of part-time workers.

The effects of different characteristics on the preference for leisure of both adults in the household are the first results to be discussed. The results from both specifications are discussed simultaneously, as they seem to be similar with respect to both the significance and direction of the effects.

To begin with the parameterised preference for leisure for the male adult, a significant negative effect[13] is found when the number of children in the household increases and when the age of the person increases (up to the age of around 31 years old). The age, where this minimum in the preference for leisure is achieved, varies slightly across the two specifications. A negative effect is further observed for households facing a higher mortgage and for households where the man and/or the woman has a high education. The only characteristic that seems to have a significant positive effect on the preference for leisure is an increase in the age once over 31 years of age.

As one would expect, the preference for leisure of the female adult seems to be much higher than that of her male partner - at least as far as this is reflected in the size of the constant term of β_2. The preference for leisure is also influenced by the sign and the size of the parameters for the quadratic terms in the utility function, which are discussed later.

A significant negative effect is observed for women in households with higher mortgage obligations and for women with high education levels. However, this last effect is only significant in the model with seven labour supply points. Surprisingly, age does not seem to have a

12 More labour supply points makes the approximation of the actual hours by the discrete points more accurate and gives a better representation of the actual eligibility for welfare of the observed households.

13 This indicates a lower preference for leisure and thus a larger taste for work.

significant influence on female preference for leisure in any of the models.

All variables related to children have a significant positive effect on the preference for leisure, except for the number of children in the model with four labour supply points, where this parameter is still positive but no longer significant. As one would expect, and as is seen in many other studies (Australian examples are Eyland, Mason and Lapsley, 1982 and Ross, 1986), having a child below five years of age has a large positive effect on the female preference for leisure. When the youngest child is between six and 12 years old a similar but much smaller effect is observed. Further, when the male partner holds a high education qualification a positive effect on the leisure preference of the woman is observed as well. Comparative advantages in the labour market seem to influence the labour supply of females, as one would expect, so a higher education level of their partner increases their value for leisure. Rather the opposite effect can be observed for men. It seems strange that when women have a higher education and are thus more competitive on the labour market, their partners apparently value leisure time less. One would expect that with a decrease of the comparative advantage of women working in the household, men would prefer to work less and spend more time in the household or at least not to work more[14].

Besides the linear terms, there are also quadratic terms involved in the translog utility function. Taking the first derivative with respect to leisure time of Person 1, the following expression for the marginal utility of leisure for Person 1 is obtained:

$$U_1 = \frac{\beta_1 + 2\alpha_{11}\ln(lhh_1) + 2\alpha_{12}\ln(lhh_2) + 2\alpha_{1x}\ln(x)}{lhh_1}$$

Similar expressions can be formulated for the leisure time of Person 2 and for net income. From this formula and the results in Table 2 we can

---

14 A possible explanation for the expected effect not being present might be that the group of men married to women with high education levels have characteristics which cause them to have lower preferences for leisure. More research and data would be necessary to find the underlying reason for the correlation between the higher education level of women and the preference for leisure of their partners.

conclude that in both models Persons 1 and 2 seem to enjoy having leisure time together. If one of the two persons has more leisure time, the marginal utility of leisure of the other person also increases. There seems to be no significant effect of income on the marginal utility of leisure time of Person 1 or vice versa. Net income and leisure time for Person 2 seem to be exchangeable. More income means that the marginal utility for leisure of Person 2 is lower and more leisure means a lower marginal utility of income.

The last parameter in Table 2 is the stigma/cost parameter associated with receipt of welfare payments. The results indicate that there is a positive and highly significant effect. This means that participating in welfare lowers the utility level of the household. Welfare payments are not just ‘free’ income for which no work has to be done, but they have a negative side effect attached to them when received by a household. Thus, there is a threshold that people need to overcome before applying for unemployment benefits. The threshold is higher when this estimated parameter is higher. It does not mean that people will not apply for welfare, but it does indicate that applying for welfare is not as attractive as some people seem to think. These results lead one to expect some households not to take up the benefits for which they are eligible, especially when low amounts of benefits are involved (as observed in the real world). Similar effects are observed in qualitative research about ‘threshold’ effects in take-up of benefits (Kerr, 1983).

To explore the economic significance of the ‘stigma’ value found, utility levels for a reference household are calculated and the difference between several situations is compared with the estimated size of the ‘stigma’ effect (see Table 3). The reference household consists of a man and a woman, each aged 30 years, without children. Both persons have a low educational level and there is no outstanding mortgage. Using the estimated parameters from model B it is found that an exogenous increase of $50 in non-labour weekly income, which raises total weekly income from $150 to $200 (before any resultant change in labour supply is taken into account), is insufficient to offset the disutility arising from participation in welfare; that is, to a first approximation, the stigma effect in monetary terms is not less than $50 per week. The increase in income would only result in a rise in utility of about three units.

Table 3: Utility Levels (Excluding the 'Stigma' Effect) for Some Typical Households[a]

Without children		**Two children, the youngest under five**	
situation	utility	situation	utility
x=150, h1=30, h2=0	184.98	x=200, h1=30, h2=0	209.49
x=170, h1=30, h2=0	186.23	x=220, h1=30, h2=0	210.53
x=200, h1=30, h2=0	187.93	x=250, h1=30, h2=0	211.98
x=170, h1=0, h2=0	189.77	x=220, h1=0, h2=0	213.87
x=170, h1=0, h2=20	184.57	x=220, h1=0, h2=20	207.56
x=170, h1=20, h2=20	182.51	x=220, h1=20, h2=20	205.64
x=200, h1=0, h2=20	186.61	x=250, h1=0, h2=20	209.29

Note: a) The typical household consists of a man and a woman of 30 years of age. Both persons have a low education level and there is no outstanding mortgage.

If the male partner can earn $170 per week by working 30 hours, this would be preferred over not working and receiving the same amount in benefits. The female preference for leisure is much higher: according to the model, she would decline to work 20 hours unless more money could be earned than by participation in welfare. An additional $30 per week, however, would make working preferable over not working and being on welfare. Having children makes working an even less attractive option for women, while for men not much seems changed.

From this example, it is clear that the size of the stigma parameter is relevant in terms of changing the preferred options. On several occasions, the difference in utility levels between the different options open to the household is smaller than the size of the stigma parameter. This means that adding the stigma term can change preferences from being on welfare to not being on welfare.

Similar significant results have also been found in other studies. In Hoynes (1996), a significant stigma effect of participation in welfare on the utility level of two-adult households in the US can also be seen. In the same study, in an alternative specification, the stigma parameter has been made dependent on personal characteristics. However, none of these variables is estimated to have a significant effect. Moffitt (1983) found a strongly significant stigma effect for female heads in the US. He also analysed the relation between the amount of benefits received and this effect and found no significant relationship. This seems to indicate that welfare recipience per se has a negative effect on utility, which is invariant with respect to the amount received. Hagstrom (1996) estimates labour supply and welfare (food stamp) participation jointly for married couples, also in the US. He does not have an explicit stigma parameter, but there is evidence of several variables that have a negative effect on welfare participation. Assets and other income decrease welfare participation, which Hagstrom explains by the positive relationship of assets with the stigma of receiving food stamps. Smith (1997), however, estimates a non-significant stigma coefficient. Compared to the other articles, the percentage of people participating in the welfare program is relatively high in his data. This might be partly explained by the fact that his US data consist of lone mothers only. The stigma or costs involved with welfare might be of less importance to them because they have children to care for and working might just not be an option for them.

Finally, we report the values of the maximised expected log likelihood functions for the specifications and the values of the maximised expected log likelihood functions when no personal or household characteristics are included. Although there is some uncertainty with respect to the exact values of the log likelihood functions, the difference in log likelihood from one to the next iteration is never more than 10 after a certain degree of convergence has been reached. In both specifications, the test statistic, comparing the model with several exogenous variables to the model with only a constant term, has a value of more than 600. This indicates that including all the characteristics certainly improves the model, as the relevant critical value $\chi^2(20)$ is 31.41 at the five per cent level. Therefore, with regard to this test, the inaccuracy is unlikely to be important.

The translog utility function is not automatically quasi-concave. Therefore, one needs to check for it after estimation in the way that is explained in Section 4.1. It is found that the first condition is fulfilled for both specifications in 100 per cent of the cases. The second condition is fulfilled for 99.96 per cent of the cases in Model A and for 97.63 per cent of the cases in Model B. The conditions have been checked for all possible values of hours for each record, taking average fulfilment percentages per record. From the above results, it can be concluded that the utility function is quasi-concave in a vast majority of the cases.

5.2 Uncompensated Wage Elasticities

One way of illustrating the implications of the results found here, is to calculate elasticities. Ninety per cent confidence intervals are calculated for each elasticity of interest by using simulation techniques. Parameter values for our labour supply model are drawn from a multivariate normal distribution with the vector containing our point estimates as its mean and the variance-covariance matrix of the parameter estimates as its variance. We draw 1000 independent sets of parameter values and calculate the implied elasticities. The width of the resulting range of elasticity values indicates how accurate the elasticities are that can be calculated from the model. Own-wage and cross-wage elasticities are calculated for both Persons 1 and 2 in six different typical households. The typical households studied are couples without children and with two children (where the youngest is under five years) on three different wage rate levels (low, average and high). A low wage here means Person 1 has a gross wage rate of $6 per hour and Person 2 has a gross wage rate of $5 per hour. Average wage rates of respectively $11.26 and $9.75 per hour have been used[15]. ‘High’ wages here are $17 for Person 1 and $15 for Person 2. The results are reported in Table 4.

It is clear from the table that the own-wage and cross-wage elasticities at low wage levels are in most instances higher in absolute terms than in the cases with higher wages. It is interesting to note that for low wage rates (and low hours) male elasticities are also high, which is an unusual finding. Fraker and Moffitt (1988) find that own-wage elasticities for female heads of households decrease with an increase in the wage rates. Thus, the above high-wage elasticities for males earning lower wage rates seem to be similar to what they find for female heads. In the lower wage households, the cross wage elasticities are also positive, which is unusual. However, one can imagine that households on low income are highly likely to be eligible for unemployment benefits. This implies that the marginal tax rate can drop considerably with an increase of family income above the level where benefits are still payable. This drop could

15 These were the average wages in November 1986, as reported in the *Yearbook Australia 1988* (ABS, 1989: 323).

Table 4: Labour Supply and Welfare Participation Elasticities[a] Using Model B[b]

	lab.sup elasticity person 1			lab.sup elasticity person 2			Welfare part. elasticity		
	Q50[e]	**Q5**	**Q95**	**Q50**	**Q5**	**Q95**	**Q50**	**Q5**	**Q95**
Low wage families[c] no children									
	E(h1)[d] = 37.87			E(h2) = 11.43			E(dW) = 0.10		
Wage1	0.831	0.611	1.122	0.404	0.207	0.662	-6.841	-7.344	-6.331
Wage2	0.106	0.047	0.177	2.320	2.174	2.465	-1.982	-2.276	-1.721
Low wage families, two children, where the youngest is between 0 and 5 years old									
	E(h1) = 26.76			E(h2) = 3.08			E(dW) = 0.44		
Wage1	2.688	2.151	3.234	1.506	1.227	1.756	-4.412	-5.101	-3.734
Wage2	0.212	0.161	0.266	1.634	1.494	1.763	-0.425	-0.502	-0.355
Average wage families[f] No children									
	E(h1) = 41.64			E(h2) = 33.78			E(dW) = 5.04 10^{-5}		
Wage1	0.173	0.152	0.193	-0.046	-0.103	0.005	-7.448	-7.842	-7.056
Wage2	-0.118	-0.143	-0.094	0.836	0.710	0.963	-5.815	-6.300	-5.361
Average wage families, two children, where the youngest is between 0 and 5 years old									
	E(h1) = 42.53			E(h2) = 13.09			E(dW) = 1.87 10^{-3}		
Wage1	0.148	0.125	0.169	-0.370	-0.452	-0.280	-7.789	-8.214	-7.363
Wage2	-0.087	-0.107	-0.068	2.034	1.929	2.134	-2.585	-2.946	-2.279
High wage families[g] no children									
	E(h1) = 41.24			E(h2) = 42.44			E(dW) = 1.13 10^{-7}		
Wage1	0.121	0.106	0.136	-0.046	-0.103	0.005	-7.448	-7.842	-7.056
Wage2	-0.105	-0.126	-0.085	0.836	0.710	0.963	-5.815	-6.300	-5.361
High wage families, two children, where the youngest is between 0 and 5 years olds									
	E(h1) = 41.65			E(h2) = 22.48			E(dW) = 1.24 10^{-5}		
Wage1	0.091	0.074	0.110	-0.230	-0.297	-0.167	-7.390	-7.779	-7.047
Wage2	-0.117	-0.140	-0.093	0.961	0.877	1.049	-4.196	-4.599	-3.816

Notes: a) All elasticities are calculated for a typical household with the following characteristics: both adults are 35 years old, have a medium level education and do not have a mortgage. Other non-labour income is 10 dollars per week for both persons.

b) See the description of the models in the footnotes to Table 2.

c) Person 1 has a wage rate of \$6 per hour and Person 2 has a wage rate of \$5 per hour.

d) E(h1) indicates the expected value of hours worked by Person 1 for the typical household. Similar expressions are used for the hours worked by Person 2 and the probability of welfare participation.

e) Q50 indicates the median value of the elasticity, Q5 indicates the fifth percentile and Q95 indicates the ninety-fifth percentile.

f) Person 1 has a wage rate of \$11.26 per hour and Person 2 has a wage rate of \$9.75 per hour.

g) Person 1 has a wage rate of \$17 per hour and Person 2 has a wage rate of \$15 per hour.

encourage someone to increase working hours when the gross wage rate of the partner increases, since it would result in an increase in his or her own net wage rate.

The elasticity values for average and high wage rates in Table 4 are similar to those found in the literature. In most other research, elasticities are calculated for average persons or households. Values range from negative values (Blundell, 1997) to values of 0.15 (Van Soest, 1995). In overviews by McElroy (1981) and Killingsworth (1983: 119-25), it can be seen that the variation found in different studies is even larger. The own-wage elasticities are much lower than for the low-wage earners and cross-wage elasticities are mostly negative, except for women in households without children, where the cross-wage elasticity is virtually zero.

Female own-wage and cross-wage elasticities tend to be higher than the male elasticities[16]. This can however be partly explained by the fact that women work fewer hours. When the expected number of working hours (E(h2)) are examined, it can be seen that they increase with the wage rates, especially for women. This is what one would expect given the values for own-wage elasticities.

Households with and without dependent children can also be compared. Female labour supply drops dramatically with the presence of children. This is in line with the parameter estimates of the labour supply model in Table 2 and with results from other research. In the households with the higher wages, men seem to increase their labour supply slightly when children are present. Men with low wages however, seem to have much lower working hours and households participate more often in welfare when children are present. When looking at the low-income households[17]

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16 This is also commonly found in other studies. See for example Wales and Woodland (1976, 1977), Killingsworth (1983), Van Soest (1995), Hagstrom (1996), Hoynes (1996) and Blundell (1997).

17 These are defined as the households where both adults have a wage rate of less than seven dollars per hour. Wage rates may differ for the different possible values of hours worked. Each possible value is weighted equally within a matching group and all weights together add up to one. So for some realisations of hours worked the household may be categorised as a low-income household, while for other values of hours worked, the household falls outside this category.

with two or more children in the data set, we observe that about 31 per cent (33 out of 107) are participating in welfare, which is high compared to the rest of the population. Thus, the results found in Table 4 seem to be confirmed by the data. However, one should realise that the wages of people on welfare are not actually observed but are imputed values using estimated wage equations.

Alternatively, the lower predicted hours of work might be partly caused by the fact that Family Income Supplementation[18] (FIS) is not included in the model. FIS was a scheme that allowed people on low incomes to apply for additional family support of $17 per child per week. The same amount was also available to people with children on unemployment benefits as an additional benefit. Our model could be extended by an additional choice to apply for FIS. The choices for FIS and for welfare participation are interdependent. Households can choose for one of the two welfare schemes or they can choose to participate in neither. By not including FIS in the model, families with children appear to have more to lose when not participating in welfare than childless families, resulting in the lower expected labour supply of men to remain eligible for welfare. However, the number of households actually receiving FIS payments in the current data set is very low, as are most of the amounts paid. Whiteford and Doyle (1991) also found that take-up of FIS was very low. In addition, the quality of the information seems poor, since in some cases FIS is stated to be paid to relatively high-income households. We decided to leave the choice for participation in FIS out of the model for the moment[19], as it would also complicate estimation.

The elasticity of welfare participation has the expected sign in all cases. It is clear that it is much more responsive to male than female wage rates in the cases where women only work few hours. An increase of the woman's wage rate in these instances has little impact on the decision on welfare participation, since her additional income contribution is only small. Therefore, the increase might not be sufficient to become independent of welfare. It is also obvious from the table that families

18 FIS was the predecessor of the current higher rate of Family Payment.

19 We actually decided to leave income from FIS out of the model altogether, as take-up was so low.

with adults on low market wages are more likely to participate in welfare than others are. For households with the highest wage rates, the expected welfare participation is extremely low.

5.3 Policy Simulations

The final analysis in this study compares the actually observed levels of labour supply and welfare participation to those predicted by the model with seven discrete labour supply points (see Table 5). For men, the 40 to 49 hours category is heavily overpredicted and there are too many part-time workers in the lowest hours categories (one to 29 hours). Many other models have also had this problem of overprediction of part-time hours. Van Soest (1995) suggests that this may be caused by not taking into account the fact that the demand for part-time workers is low, so there are restrictions in the offered hours of work. Here the overprediction is not extreme for either men or women. According to Table 5, in our model women are too often categorised as non-participants, low hours part-time workers and as working over 50 hours (although the discrepancy is modest in the first two cases).

The number of welfare participants predicted in the simulation and the actual number of welfare participants are similar. There is, however, a striking difference between the simulated and the actual hours worked by men in households on welfare. Looking at our model and at the unemployment benefits rules this might not be so surprising as thought at first sight. At zero or low hours of labour supply, people normally have lower preferences for leisure and the first $30 of income does not have any impact on benefit payments. The next $40 is deducted from the benefits at a rate of 50 per cent and after that any additional earnings are deducted on a dollar for dollar basis. Given that one participates in welfare, working a low number of hours is likely to be optimal, since the marginal preference for leisure and the marginal tax rate are likely to be low at that level of labour supply. After the first few hours the deduction rate in the benefit scheme increases to 100 per cent, so working more hours then becomes a less attractive alternative. In reality, jobs with low hours are scarce, so households (especially their male adult members) might be restricted in their labour supply and not be able to work at all.

Table 5: Actual and Simulated Labour Supply of Men and Women in our Data Set

	Men				Women			
Hours	Actual	Sim.	Sim.1[(a)]	Sim.2[(b)]	Actual	Sim.	Sim. 1	Sim. 2
Non-welfare participants								
0	87	9	7	9	982	1172	1131	1176
1 - 9	5	11	13	11	91	64	54	60
10 - 19	5	25	21	26	196	199	203	205
20 - 29	22	29	28	29	174	244	237	240
30 - 39	636	270	266	270	380	207	204	208
40 - 49	967	1686	1631	1684	309	144	138	138
≥ 50	444	139	143	138	34	139	142	142
Welfare participants								
0	104	1	3	1	102	106	166	108
1 – 9	2	104	161	106	3	0	0	0
10 - 19	1	1	2	1	1	0	0	0
20 - 29	1	0	0	0	1	0	0	0
30 - 39	1	0	0	0	1	0	0	0
40 - 49	0	0	0	0	1	0	0	0
≥ 50	0	0	0	0	0	0	0	0

Notes: a) Simulation with a 10 per cent increase in the unemployment benefit level.

b) Simulation with a 10 percentage point decrease (from 100 per cent to 90 per cent) in the highest deduction rate of earned income from benefits.

From these simulations, we have calculated the expected welfare participation to be equal to 5.4 per cent; the expected hours worked by Person 1 is 40.18 hours and by Person 2 is 16.41 hours. After simulating an increase in the maximum benefit level by 10 per cent, the expected values are respectively: 7.5 per cent, 39.50 hours and 16.28 hours. A decrease in the highest withdrawal rate for earned income by 10 percentage points from 100 per cent to 90 per cent produces expected values of: 5.7 per cent, 40.14 hours and 16.40 hours.

The 10 percentage point decrease in deduction rates does not seem to have much effect on labour supply. These results are similar to those of Moffitt (1983), Fraker and Moffitt (1988), Hoynes (1996), Hagstrom (1996) and Keane and Moffitt (1996). A 10 per cent increase in the benefit level has more effect, although still not a very large one. Moffitt (1983), Fraker and Moffitt (1988), Hoynes (1996) and Hagstrom (1996) find larger effects for this change as well. Keane and Moffitt (1996) do not perform this simulation. Comparing their results to those of the present study is hard since the percentage change in the benefit level is different for all the studies cited. The population which Moffitt (1983), Fraker and Moffitt (1988), and Keane and Moffitt (1996) used in their studies is different from our population as well, so that the welfare participation rates in their samples are much higher than those in our sample. Hoynes (1996) and Hagstrom (1996) have a reasonably comparable sample of two-adult households with only slightly higher participation rates in welfare. Overall, it can be concluded that the model estimated here seems to dictate similar behaviour patterns with respect to changes in deduction rates and maximum benefit levels as the models estimated in the above articles.

6 Conclusion

The adapted EM algorithm seems to work reasonably well for the data set used in this paper. The results from the wage equation are in line with the results of other researchers. The labour supply estimates are mostly consistent with the existing literature and so are the estimated elasticities.

The additional parameter to measure disutility from welfare participation together with the introduction of the welfare participation choice into the model means that the model allows for households who are eligible for welfare, but are not taking up their benefits. A model without this choice might result in an overestimation of the welfare participation rate. It is found that the additional parameter to measure disutility from welfare participation is significant in both a statistical and an economic sense. Welfare participation choice is an important issue when one is interested in the effect of changes in welfare payments.

Simulating policy changes, using the estimated model, can give some insight into the implications of the model. From the simulations performed in this study, it can be seen that neither changing the benefit level nor a change in the withdrawal rate of the benefits seem to have a large effect on labour supply.

The choice for a multinomial logit model has made estimation relatively simple. Even in this case where the necessity to apply a simulated EM algorithm complicated matters, estimation was reasonably quick. With better data, the multinomial logit model could probably easily deal with more than seven labour supply points for both partners in a household. The multinomial logit has the disadvantage that the error terms can only be interpreted as optimisation errors and do not reflect random preferences. An extension of the model, to allow for unobserved heterogeneity in some of the parameters, could deal with this disadvantage.

Plans for future research involve firstly, more adequate modelling of the unobserved wage rate, so that at least the large standard errors involved in the imputed wage rate values are taken into account. Ideally, the parameters of the wage equation are estimated simultaneously with the parameters of the labour supply model. Secondly, the influence of demand side restrictions on the actual working hours should be taken into account. Thirdly, the choice for other welfare payments (e.g. additional family payments or rent assistance) could be included in the model. Finally, from a policy point of view it is important to estimate the model with more recent data, as for example, the Survey of Income and Housing of 1994-1995 and/or 1995-1996.

Appendix One: Tax and Benefit Rules 1986/87

Since only couples with or without children are part of this study, the overview is restricted to this group.

Unemployment Benefits[20]

Maximum rate for couples	$177.10 per week
per additional child	$17.00 per week (no tax)
Income test: free area (0 % reduction)	$0.00-$30.00 per week
50 % reduction of benefit	$30.00-$70.00 per week
100 % reduction of benefit	more than $70.00 per week

Family Allowance

For families with children younger than 16 years old, or children of 16 or 17 years old, who are dependent students, or children of 18 to 24 years old, who are from disadvantaged families.

Rate:	1 child	$ 5.25 per week
	2 children	$12.74 per week
	3 children	$21.71 per week
	4 children	$30.69 per week
	each additional child	+ $10.48 per week

There is neither tax nor an income test on family allowance.

Family Income Supplement

Not available for beneficiaries or pensioners, who have additional child support integrated in their benefit or pension.

Maximum rate	$17.00 per week per child (no tax)
Income test: free area	$0.00-$241 per week
50 % reduction	more than $241.00 per week

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20 The details of the benefits are taken from the annual report of the Department of Social Security (1986). The rules, described here, are as they were at 30 June 1986.

Tax Rates[21]

Tax free area	$0.00-$93.79 per week
24.42 %	$93.80-$239.74 per week
26.50 %	$239.75-$241.66 per week
29.42 %	$241.67- $373.99 per week
44.25 %	$374.00-$537.02 per week
46.83 %	$537.03-$671.27 per week
57.08%	more than $671.27 per week

Tax Rebates

For a dependent spouse with children:

Maximum rate	$19.75 per week (on taxable income of main earner)
Income test: free area	spouse earns less than $34.25 per week
25 % reduction	spouse earns more than $34.25 per week

For a dependent spouse without children:

Maximum rate	$15.92 per week (on taxable income of main earner)
Income test: free area	spouse earns less than $5.41 per week
25 % reduction	spouse earns more than $5.41 per week

For beneficiaries:

Maximum rate	$5.37 per week
Income test: free area	income of couple is less than $180.97 per week
12.5 % reduction	income of couple is more than $180.97 per week

Medicare Rates

Levy rate	1%
Free area	$239.82 + (number of children) * $29.34

21 The taxation rules as described here are taken from the Taxation Statistics of 1986/1987 published by the Australian Taxation Office (1989).

Appendix Two: The Adapted EM Algorithm

The EM algorithm is often used in situations where data are missing or where variables are censored. The problem in this research is of a similar nature. The values of one variable are in a different file. Records in the two files cannot be matched on an individual basis, but only per group (these groups are called matching groups). The number of possible different values for the variable in the separate file ranges from one to the number of observations in the matching group. The difference with missing or censored variables and the problem in this research is that the number of possible values for each variable is finite.

The EM algorithm is normally used in a continuous context, but because of this finite number of possible values, a discrete approach is more appropriate. Each value in a matching group can at most be used as many times as it occurs in the matching group. This means that a combined likelihood expression for all households in one matching group has to be evaluated instead of an expression for each individual household, because selecting a value for one observation often restricts the choice of values for the other households in the same group.

Assume the model of interest is a simple linear regression:

$$Y^* = X'\beta + u \qquad \text{with } u \sim N(0,\sigma^2) \tag{A.1}$$

The dependent variable Y* is the variable in the separate file. Within each matching group j, there is choice from n_j values $y_{1j},\ldots,y_{n_j j}$ for the m_j observations on the vector of independent variables $X_{1j},\ldots,X_{m_j j}$. β and σ^2 are parameters that have to be estimated and u represents the error term.

The likelihood function can be constructed by taking the joint probability density functions for observations per matching group:

$$L(\theta \mid A_1,\ldots,A_G) = \prod_{j=1}^{G}\;{}_{i=1}^{n_j} \cdots \;{}_{\substack{p=1\\ p\neq i,k,..}}^{n_j} \mathrm{pdf}\left| Y^*_{1j}=y_{ij}, Y^*_{2j}=y_{kj},\ldots,Y^*_{m_j j}=y_{pj} \right| \theta, X_{1j},\ldots,X_{m_j j} \Big|$$

$$= \prod_{j=1}^{G} \sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} \mathrm{pdf}\left(Y_{1j}^{*} = y_{ij} \middle| \theta, X_{1j} \right) \ldots \mathrm{pdf}\left(Y_{m_j j}^{*} = y_{pj} \middle| \theta, X_{m_j j} \right) \qquad \text{(A.2)}$$

where

G is the number of matching groups in the two data sets,

n_j is the size of matching group j,

θ is the vector consisting of β and σ^2 that has to be estimated,

$A_j = \{y_{1j}, y_{2j}, \ldots, y_{n_j j}\}$ for j=1,...,G, and

pdf = probability density function.

Taking logarithms to obtain the log likelihood:

$$l(\theta | A_1,\ldots,A_G) = \sum_{j=1}^{G} \ln \left[\sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} \mathrm{pdf}\left(Y_{1j}^{*} = y_{ij} \middle| \theta, X_{1j} \right) \ldots \mathrm{pdf}\left(Y_{m_j j}^{*} = y_{pj} \middle| \theta, X_{m_j j} \right) \right] \qquad \text{(A.3)}$$

Instead of the integration over a range of possible values for a missing or censored variable, in this discrete version of the EM algorithm, a summation over all possible combinations of values for the variable Y* is performed.

Using the EM algorithm results in a rewritten log likelihood expression (see Dempster, Laird and Rubin, 1977):

$$l(\theta \ A_1,\ldots,A_G) = Q(\theta, \varphi; A_1,\ldots,A_G) - H(\theta, \varphi; A_1,\ldots,A_G) \qquad \text{(A.4)}$$

φ is a vector defined over the same domain as θ and the above is valid for any value of φ.

Applying the EM algorithm to the problem of the scrambled data sets and assuming a distributional form: pdf(y* θ,X) = f(y* θ,X), the expression Q can be calculated. Assuming that f(y* θ,X) is known,

$\Pr(Y^*_{1j}, Y^*_{2j}, \ldots, Y^*_{m_j j} \mid \theta, A_j)$ can be constructed for each matching group A_j:

$$\Pr(Y^*_{1j} = y_{ij}, \ldots, Y^*_{m_j j} = y_{pj} \mid A_j, \theta)$$

$$= \frac{\mathrm{pdf}\left(Y^*_{1j} = y_{ij} \mid X_{1j}, \theta\right) \ldots \mathrm{pdf}\left(Y^*_{m_j j} = y_{pj} \mid X_{m_j j}, \theta\right)}{\sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} \mathrm{pdf}\left(Y^*_{1j} = y_{ij} \mid X_{1j}, \theta\right) \ldots \mathrm{pdf}\left(Y^*_{m_j j} = y_{pj} \mid X_{m_j j}, \theta\right)}$$

$$= \frac{f(y_{ij} \mid X_{1j}, \theta) \ldots f(y_{pj} \mid X_{m_j j}, \theta)}{\sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} f(y_{ij} \mid X_{1j}, \theta) \ldots f(y_{pj} \mid X_{m_j j}, \theta)} \quad \text{for } \{y_{ij}, \ldots, y_{pj}\} \subset A_j$$

$$= 0 \qquad \text{elsewhere} \tag{A.5}$$

This conditional probability density function is of major importance in the EM algorithm. In the function Q the contribution $\log(f(\theta, y^*))$ of an unobserved latent variable y^* to the log likelihood function is replaced by its expectation over the set of values in which its true value is known to lie. Summing over all matching groups j, the following expression results:

$$Q(\theta, \theta^{q-1}; A_1, \ldots, A_G) = \sum_{j=1}^{G} \sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} \Big\{ \ln\left[f\left(y_{ij} \mid \theta, X_{1j}\right)\right] + \ln\left[f\left(y_{kj} \mid \theta, X_{2j}\right)\right] + \ldots$$

$$+ \ln\left[f\left(y_{pj} \mid \theta, X_{m_j j}\right)\right] \Big\} \frac{f\left(y_{ij} \mid X_{1j}, \theta^{q-1}\right) \ldots f\left(y_{pj} \mid X_{m_j j}, \theta^{q-1}\right)}{\sum_{i=1}^{n_j} \sum_{\substack{k=1 \\ k \neq i}}^{n_j} \cdots \sum_{\substack{p=1 \\ p \neq i,k,..}}^{n_j} f\left(y_{ij} \mid X_{1j}, \theta^{q-1}\right) \ldots f\left(y_{pj} \mid X_{m_j j}, \theta^{q-1}\right)} \tag{A.6}$$

This Q-function has to be maximised with respect to θ, where θ^{q-1} is given. Dempster, Laird and Rubin (1977) have shown that iteratively maximising this function using the previous optimal values θ^{q-1} leads to convergence. Only an arbitrary value θ^0 is needed to start the process and the iterations are finished when $\theta^q = \theta^{q-1}$. This procedure leads to an estimated θ that is a stationary point of the log likelihood function. Since the θ found in this way is not necessarily a maximum, second order conditions should be checked. If we experiment with some different starting values, we may be reasonably certain that the maximum found is global.

Table A.1: A Probit Model of the Labour Force Participation of Men and Women

	Men		Women	
	Parameter	t-ratio	Parameter	t-ratio
Constant	-2.6359	-3.36	-2.1603	-3.47
Number of children (no children)				
• number = 1-2	-0.2357	-1.32	-0.0544	-0.40
• number > 2	-0.4626	-2.06	0.0722	0.43
Age of youngest child (no/older children)				
• youngest child 0-4	0.1843	0.97	-0.5972	-4.50
• youngest child 5-12	0.1443	0.73	-0.2354	-1.77
log(outstanding mortgage)	0.0058	0.52	0.0081	1.11
log(other non-labour income)	-0.0876	-3.15	-0.0442	-2.10
log(wage income of partner)	0.0583	2.88	0.0569	2.88
State (New South Wales)				
• Victoria	-0.1580	-1.02	-0.1512	-1.45
• Queensland	-0.0042	-0.03	-0.1805	-1.64
• South Australia	-0.2461	-1.46	-0.0040	-0.03
• West Australia	-0.1009	-0.60	-0.0958	-0.83
• Tasmania	0.2622	1.11	-0.1912	-1.28
• Territories	-0.2764	1.05	0.0946	0.53
Age/100	8.6852	2.22	6.8545	2.05
$(Age/100)^2$	-11.557	-2.46	-11.143	-2.54
Ethnicity (dummy variable)	0.7241	2.61	0.3354	1.94
Work experience previous year in weeks	0.0550	18.69	0.0470	28.31
Education (no school/ left before 14)				
• left school at age 14 or 15	0.1303	0.60	0.0932	0.46
• left school older than 15	0.4260	1.74	0.1762	0.83
• secondary school/qualification	0.4225	1.69	0.1449	0.65
• trade certificate (no field)	0.0769	0.23	-0.3357	-0.80
• trade certificate (technical)	0.2739	1.25	0.2535	0.94
• trade certificate (miscellaneous)	0.2435	0.77	[a]	
• other certificate./diploma (business, commerce)	0.5905	1.86	0.1905	0.86
• other certificate/diploma (social sciences, arts)	[a]		-0.1535	-0.40
• other certificate/diploma (education)	0.5805	1.02	0.6008	2.35
• other certificate/diploma (medical)	0.8673	2.50	0.3088	1.32
• other certificate/diploma (technology)	[a]		0.2617	0.55
• bachelor or higher (business, commerce)	1.4802	2.80	0.2879	0.67
• bachelor or higher (social sciences, arts)	[a]		0.2217	0.73
• bachelor or higher (education)	0.8264	1.52	0.4833	1.66
• bachelor or higher (medical, technology)	0.7045	2.03	0.7482	2.00
• other qualification	1.0446	1.29	-0.3150	-0.93
ln(L)	-373.072		-836.104	
ln(L(0)) [b]	-734.876		-1625.484	
Adjusted pseudo-R^2 [c]	0.49		0.48	
	Predicted Participation			
Actual participation	no	yes	no	yes
no	131	91	963	155
yes	34	2093	182	1049

Notes:

a) This category and the previous one are aggregated.

b) Log(L(0)) is the maximum log likelihood function when all parameters except the Constant are set to zero.

c) This is calculated by $1 - \frac{\ln(L)/(T-k)}{\ln(L(0))/(T-1)}$, where k is the number of independent variables.

Table A.2: Estimated Wage Equation for Males and Females Using the EM Algorithm

	Males		Females	
	Parameter	t-ratio[(a)]	Parameter	t-ratio
Constant	1.1548	7.050	1.1087	5.808
State (New South Wales)				
• Victoria	-0.0309	-1.593	0.0076	0.319
• Queensland	-0.0385	-1.915	-0.0613	-2.331
• South Australia	-0.0604	-2.696	0.0384	1.396
• West Australia	0.0317	1.510	-0.0153	-0.563
• Tasmania	-0.0412	-1.482	-0.0948	-2.764
• Territories	0.0979	3.012	0.0795	2.202
Age/10	0.3085	6.270	0.2092	3.146
$(\text{Age}/10)^2$	-0.0327	-5.361	-0.0258	-2.899
Ethnicity (dummy variable)	0.0407	1.028	-0.0616	-1.391
Work experience previous year in weeks	0.0077	3.850	0.0078	4.105
Education (no school/ left before 14)				
• left school at age 14 or 15	0.0390	0.944	0.1917	3.238
• left school older than 15	0.0858	1.946	0.2107	3.465
• secondary school/qualification	0.1606	3.667	0.2316	3.748
• trade certificate (no field)	0.0526	0.963	0.2203	2.088
• trade certificate (technical)	0.1263	3.058		
• trade certificate (miscellaneous)	0.0452	0.906	0.1832[(b)]	2.552
• other certificate/diploma (business, commerce)	0.3341	6.669	0.2619	4.238
• other certificate/diploma (education)	0.2351	3.685	0.4464	6.764
• other certificate/diploma (medical)	0.2605	3.314	0.3894	6.171
• other certificate/diploma (technology)	0.3291	6.675	0.6986	6.160
• other certificate/diploma (social sciences, arts)	-0.0073	-0.070	0.2936	3.068
• bachelor or higher (business, commerce)	0.4872	8.810	0.6373	6.367
• bachelor or higher (education)	0.3318	5.567	0.6199	8.932
• bachelor or higher (medical)	0.4500	4.649	0.7512	6.956
• bachelor or higher (technology)	0.4681	9.612	0.6867	7.803
• bachelor or higher (social sciences, arts)	0.3198	4.935	0.5347	7.416
• other qualification	0.0818	1.038	0.2102	2.359
Correction term	0.1477	1.581	0.2493	3.531
Variance	0.0784	30.154	0.0653	22.517
Number of observations	2102		1201	
E(ln(L))	1625.12		1038.44	
McFadden Measure[(c)]	0.10		0.29	
Percentage hours in correct category	27.3		37.8%	

Notes: a) The values for these t-ratios are an overestimate of the real values, as the extended formula for the covariance matrix to account for the estimation of the Heckman term P was not used.

b) The categories technical and miscellaneous trade certificate are taken together.

c) McFadden, Puig and Kirschner (1977) proposed a prediction success index for a probabilistic choice model:

$$psi = \sum_{i=1}^{m} \left| \frac{n_{ii}}{n_{..}} - \frac{n_{.i}^2}{n_{..}^2} \right| \Bigg/ \left[1 - \sum_{i=1}^{m} \left(\frac{n_{.i}^2}{n_{..}^2} \right) \right]$$

$n_{..}$ is the total number of observations,
n_{ii} is the number of correct predictions for alternative i,
$n_{.i}$ is the number of observations predicted to choose alternative i.
The maximum value of this index is one.

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