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by Hans G. Bloemen

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Abstract

A model of labour supply is formulated in which individual labour force participants are assumed to be restricted in their choice by the job offers which arrive randomly from a job offer distribution. A job offer consists of a wage component and an hours component. The number of jobs offered to an individual is random and individuals will choose the wage-hours package which generates the highest utility level.

The model is to provide a link between static models of labour supply in which individuals are subject to hours restrictions and in which no allowance is made for an independent wage offer effect, and dynamic models from job search theory in which the wage rate is assumed to be the only job component, thereby implicitly assuming that individuals are not faced by hours restrictions.

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1 Introduction

In this paper a model of labour supply is set up in which individuals are restricted in their choice by the job offers that are offered to them by the employers. In the mid-eighties it was recognized that the standard neo-classical labour supply model (see e.g. Heckman (1974), Hausman (1980)), in which wages are fixed and the optimal number of working hours can always be chosen was not in accordance with reality. Dickens and Lundberg (1985) introduced hours restrictions into the labour supply model assuming that hours arrive from a discrete offer distribution. Tummers and Woittiez (1991) extended the model by making the wage rate dependent on hours. Van Soest, Woittiez and Kapteyn (1990) compared the standard model with the model with hours restrictions using a Dutch data set on labour supply, taking into account the tax system, and their estimation results are relevant empirical evidence in favour of the hours restrictions model. In Blundell, Ham and Meghir (1987) a different approach to restrictions on the labour market is followed. Here the emphasis is on the modelling of involuntary unemployment.

Although wages can vary with the number of hours offered in these models, for example because individuals base their decisions on net wages, the possibility that wages also vary from job offer to job offer because of an independent wage offer effect is not taken into consideration. We will assume that, like in job search theory (see Mortensen (1986) for an overview), wages arrive from a wage offer distribution.

We thus make the assumption that a job offer consists of two characteristics. It has a wage component and an hours component. An individual will choose the job yielding the highest utility level. If all jobs offered generate utility levels less than the utility of not working the individual is observed to be non-working. The possibility is left open that an individual will receive no job offer at all, so involuntary unemployment may arise. Only wage-hours offers that are accepted will be observed. The distribution of the observed wages will depend on the structure of the model and therefore it is not possible to use a two-step procedure to estimate the labour supply parameters, estimating the parameters of the wage ditribution separately. All parameters of the model have to be estimated simultaneously.

As opposed to previous studies, like Tummers and Woittiez (1991) and Van Soest, Woittiez and Kapteyn (1990), the distribution of the number of job offers is made dependent on individual characteristics. It is tested for the significance of the dependence of the average number of job offers on individual characteristics. Particular attention is paid to the effects on the parameter estimates of the utility function, as the introduction of an individual specific number of job offers turns out to have serious consequences for these estimates.

The model is estimated both with and without hours dependence of the wage equation, which enables us to test for the significance of hours in the wage equation. The estimates of the specification with hours in the wage equation provide a different explanation for observing low frequencies of weekly working hours than specifications without hours dependent wages.

Simulation experiments are performed to compare the empirical frequency distribution of working hours with the frequency distribution that is generated by the model.

Moreover, it is tested formally whether the simulated hours distribution and the empirical hours distribution are equal.

In section 2 we present the model and formulate the likelihood function. In section 3 the maximum likelihood estimates of various model specifications are presented. Simulation experiments and formal testing procedures are performed. Finally, in section 4, some concluding remarks are made.

2 The model

The model assumes that the individual cannot supply the optimal number of working hours which results from maximizing utility subject to a budget constraint, like in the standard labour supply model, in which typically no involuntary unemployment can occur, see e.g. Heckman (1974) and Hausman (1980). Instead, it is assumed that the individual, at a given point in time, receives a random amount of job offers from the employers. A job offer is characterized by a wage rate and a weekly number of working hours. The job offers are compared to each other by their utility level. The individual selects the job with the highest utility level, which is compared with the utility level of not working, after which it is decided whether or not the job is accepted. Note that the model is fully static in the sense that all job offers arrive at a given point in time and the job acceptance decision is made immediately, without taking into account the possibility of future job offers. Therefore, the model can be estimated with cross section data. In Bloemen (1992) a sequential job search model is presented in which a job not only has a wage component, as is usual in the standard job search model, see e.g. Mortensen (1986), but has an hours component as well, as in the (static) Dickens and Lundberg (1985) model. In this sequential search model, apart from data on labour supply and the wage rate, use is made of duration data in the estimation of the model, so the availability of a panel survey is a requirement. In making the job acceptance decision the expectations with respect to possible future job offers are taken into acount as well.

The present model provides a link between the static Dickens and Lundberg (1985) model, in which only the number of working hours varies from job offer to job offer, and the standard job search model in which the wage rate is the only job component.

The number of job offers is assumed to be Poisson distributed with parameter λ. An advantage of this specification, as opposed to the binomial specification of Tummers and Woittiez (1991) and Van Soest et al. (1990), is that it can easily be made dependent on individual characteristics. In these previous studies, the effect of individual characteristics, like age and the level of education, on the number of job offers, have typically been ignored. Moreover, in the binomial distribution a fixed maximum number of job offers has to be chosen in advance.

A job offer is modelled as a simultaneous draw of a wage rate w and a weekly number of working hours h from a joint wage hours offer distribution $f(w, h)$.

As in the Dickens and Lundberg (1985) approach we assume that there is a discrete hours offer distribution defined over m fixed numbers of positive hours $h_l, l = 1, ..., m$. That is, hours are grouped into m categories, where the probability of drawing from category l is given by p_l. The advantage of this approach is that no heavy restrictions, like single peakedness or symmetry, are placed on the shape of the distribution. The price which has to be paid for this flexibility of the shape of the hours distribution is that labour supply can only take a discrete number of values.

$$P(h = h_l) = p_l, l = 1, ..., m \tag{2.1}$$

In the estimation the probabilities can be parametrized as

$$p_l = \frac{\mu_l}{\sum_{k=1}^{m} \mu_k}, \mu_1 = 1 \tag{2.2}$$

in which μ_1 has been normalized to 1 and the remaining μ_l are nonnegative.

The wage rate, conditional on $h = h_l$, is assumed to be lognormally distributed. Tummers and Woittiez (1991) also estimated the wage distribution jointly with the labour supply probabilities, but they use a normal wage distribution, thereby not restricting the range of possible wages to positive values. The wage specification becomes

$$\ln w = x_l' \eta + v \tag{2.3}$$

$$v \sim N(0, \sigma_v^2) \tag{2.4}$$

or equivalently

$$w = \exp(x_l' \eta) u \text{ with } u = \exp(v) \tag{2.5}$$

in which the subindex l indicates possible dependence on h_l. The job joint job offer density function becomes

$$f(w, h_l) = \frac{1}{\sqrt{2\pi}} \frac{1}{w} \exp\left\{ -\frac{1}{2\sigma_v^2} [\ln w - \eta' x_l]^2 \right\} p_l, 0 < w < \infty, l = 1, ..., m \tag{2.6}$$

For ease of exposition it is assumed for the moment that the budget constraint is linear, ignoring the tax system.

$$y = wh + \mu \tag{2.7}$$

where μ is non-labour income.

The utility function is defined over labour supply h and income y and is indicated by $u(h, y)$. The specification of the utility function is the Hausman (1980) specification. Maximizing this utility function subject to a linear budget constraint yields a labour supply function which is linear in both non-labour income and the wage rate.

$$u(h, y) = -\ln(\gamma - \beta h) - \frac{\beta(h - X\delta - e - \beta y)}{\gamma - \beta h} \tag{2.8}$$

where

- β, γ, δ are parameters, $\beta < 0, \gamma > 0$
- y is disposable income
- h is the number of working hours
- e is an unobserved random taste variable, $e \sim N(0, \sigma_e^2)$

- X is a vector of individual characteristics

At a given point in time, an individual receives n job offers each of them consisting of a wage $w, 0 < w < \infty$ and a number of working hours $h \in \{h_1, ..., h_m\}$. Furthermore, an individual can always choose not to work. The alternative which yields the highest level of utility will be chosen. An individual will be observed to be non-working if the utility level of not working exceeds the utility level of all of the n job offers. The number of job offers is assumed to be a Poisson distributed random variable.

$$p(n) = \frac{\exp(-\lambda)\lambda^n}{n!}, n = 0, 1, ..., \infty \tag{2.9}$$

Note that it is possible that no jobs are offered at all so that individuals can be involuntarily unemployed.

In order to write down the likelihood function the likelihood contribution of non-working and working individuals will be determined separately. Suppose that for a working individual we observe the wage-hours pair (w_*, h_{l_*}), where $l_* \in \{1, ..., m\}$. The fact that (w_*, h_{l_*}) is observed means that all other job offers, if there are any, are from the set of wage-hours packages which yield at most the same utility level as the observed pair. This set has to be determined. For every level of hours $h_l, l = 1, ..., m$, the set $A_l(e)$ of wages can be determined which includes all wage levels w for which $u(h_l, wh_l + \mu) \leq u(h_{l_*}, w_* h_{l_*} + \mu)$ for a given value of e.

$$A_l(e) := \{w | u(h_l, wh_l + \mu) \leq u(h_{l_*}, w_* h_{l_*} + \mu) | e\} \tag{2.10}$$

The probability $P(w_*, h_{l_*}|e)$ of drawing an arbitrary job offer which yields at most the same utility level as the observed job (w_*, h_{l_*}) equals the probability of drawing a job offer from any of the sets $A_l(e)$, i.e.

$$P(w_*, h_{l_*}|e) := P(u(h, wh + \mu) \leq u(h_{l_*}, w_* h_{l_*} + \mu)|e) = \sum_{l=1}^{m} p_l P(w \in A_l(e)|e) \tag{2.11}$$

Using the distributional assumptions in (2.3) and (2.4) yields

$$P(w \in A_l(e)|e) = \Phi\left(\frac{\ln g_l(e) - \eta' x_l}{\sigma_v}\right) \quad \text{if } g_l(e) > 0 \tag{2.12}$$

$$= 0 \quad \text{if } g_l(e) \leq 0 \tag{2.13}$$

with $\Phi(.)$ the standard normal distribution function and

$$g_l(e) = \frac{(\gamma - \beta h_l) \ln\left(\frac{\gamma - \beta h_l}{\gamma - \beta h_{l_*}}\right)}{\beta^2 h_l} - \frac{(h_{l_*} - h_l)(\gamma - \beta X\delta - \beta e - \beta^2 \mu)}{\beta h_l(\gamma - \beta h_{l_*})} + \frac{\gamma - \beta h_l}{\gamma - \beta h_{l_*}} \frac{h_{l_*}}{h_l} w_* \tag{2.14}$$

Note that if $l = l^*$ the first two terms of (2.14) are equal to zero, whereas the last term becomes w^*.

Now assume that there are n job offers $(w_{(j)}, h_{(j)}), j = 1, ..., n$. Only the job with the highest utility level, (w_*, h_{l_*}) is observed if its utility level is higher than $u_0 = u(0, \mu)$, the utility level of not working which we will call the reservation utility level. So

$$
\begin{array}{llrcl}
(w_*, h_{l_*}) = (w_{(1)}, h_{(1)}) & \text{if} & u(h_{(1)}, w_{(1)}h_{(1)} + \mu) & > & u(h_{(j)}, w_{(j)}h_{(j)} + \mu) \\
 & & & & j = 2, ..., n \\
 & \text{and} & u(h_{(1)}, w_{(1)}h_{(1)} + \mu) & > & u_0 \\
(w_*, h_{l_*}) = (w_{(2)}, h_{(2)}) & \text{if} & u(h_{(2)}, w_{(2)}h_{(2)} + \mu) & > & u(h_{(j)}, w_{(j)}h_{(j)} + \mu) \\
 & & & & j = 1, ..., n, j \neq 2 \\
 & \text{and} & u(h_{(2)}, w_{(2)}h_{(2)} + \mu) & > & u_0 \\
 & \vdots & & & \\
(w_*, h_{l_*}) = (w_{(n)}, h_{(n)}) & \text{if} & u(h_{(n)}, w_{(n)}h_{(n)} + \mu) & > & u(h_{(j)}, w_{(j)}h_{(j)} + \mu) \\
 & & & & j = 1, ..., n-1 \\
 & \text{and} & u(h_{(n)}, w_{(n)}h_{(n)} + \mu) & > & u_0
\end{array}
\tag{2.15}
$$

The observed job is the result of any of these n possibilities and therefore, the likelihood contribution of the observed job equals n times the probability that there are $n-1$ job offers with a utility level that does not exceed the utility level of the observed job, times the wage offer density function evaluated in the observed wage rate w_*, times the probability p_{l_*} of drawing the observed number of working hours h_{l_*}. The likelihood contribution of an observed wage-hours pair, conditional on e and the number of drawings n, becomes:

$$
l(w_*, h_{l_*}|e, n) = n[P(w_*, h_{l_*}|e)]^{n-1} k(w_*, \eta' x, \sigma_v) p_{l_*} \qquad \begin{array}{r} l_* \in \{1, ..., m\} \\ u(h_{l_*}, w_* h_{l_*} + \mu) > u_0 \end{array} \tag{2.16}
$$

where $k(.)$ is the log-normal density function of wage offers. Note that if n equals zero the likelihood contribution of the observed value is zero, as observing a job is in contradiction with the occurrence of zero job offers. If $n = 1$, there is no choice among different jobs and the likelihood contribution of observing (w_*, h_{l_*}) becomes just the job offer density evaluated in the observed job.

(2.16) is multiplied by the probability that n occurs, after which we sum over all n to obtain the likelihood contribution of the observed wage-hours package, conditional on the unobserved preference parameter e:

$$
l(w_*, h_{l_*}|e) = \lambda \exp\{-\lambda[1 - P(w_*, h_{l_*}|e)]\} k(w_*, \eta' x, \sigma_v) p_{l_*} \qquad \begin{array}{r} l_* \in \{1, ..., m\} \\ u(h_{l_*}, w_* h_{l_*} + \mu) > u_0 \end{array} \tag{2.17}
$$

For an individual who is not working none of the n job offers generates a utility level which exceeds the utility level of not working, where we have to take into account that n actually may be zero. Then the probability that none of the n job offers is acceptable is given by

$$
P(h = 0|e, n) = [P(0|e)]^n \tag{2.18}
$$

where

$$
P(0|e) = \sum_{l=1}^{m} p_l P(w \in A_{l0}(e)|e) \tag{2.19}
$$

where $A_{l0}(e)$ is defined as in (2.10), with h_{l_*} replaced by zero and $g_l(e)$ in (2.12) and (2.13) is replaced by $g_{l0}(e)$, which is $g_l(e)$ with h_{l_*} replaced by zero.

Multiplying by the probability that n job offers arrive and summing over all possible n, including $n = 0$, gives the likelihood contribution of a non-working individual, conditional on e:

$$l(h = 0|e) = \exp\{-\lambda[1 - P(0|e)]\} \tag{2.20}$$

To remove the conditioning on the random preference parameter in the likelihood contribution has to be integrated over all e, $-\infty < e < \infty$. For the working individuals the likelihood contribution is zero if $u(h_{l_*}, w_* h_{l_*} + \mu) < u_0$ and therefore the effective integration region becomes

$$B := \{e | u_0 \leq u(h_{l_*}, w_* h_{l_*} + \mu)\} \tag{2.21}$$

The final likelihood contribution for an individual with a job becomes

$$l(w_*, h_{l_*}) = \int_B l(w_*, h_{l_*}|e) \frac{1}{\sigma_e} \phi\left(\frac{e}{\sigma_e}\right) de, l_* \in \{1, ..., m\}, 0 < w < \infty \tag{2.22}$$

where $\phi(.)$ is the standard normal density function. Note that the range of w is $(0, \infty)$ after having integrated out e as the region B is nonempty for every positive wage rate, i.e. there always exists a range of random preferences such that working is preferred over non-working for every positive wage rate.

For the non-working individuals the likelihood contribution becomes

$$l(h = 0) = \int \exp\{-\lambda[1 - P(0|e)]\} \frac{1}{\sigma_e} \phi\left(\frac{e}{\sigma_e}\right) de \tag{2.23}$$

If the tax system is introduced the procedure remains basically the same. The probabilities in (2.12) have to be adapted and split up in accordance with the brackets in the tax system.

3 Estimation results

The model is estimated using a sample of 849 married women in theyear 1985, obtained from the Organization for Strategic Labourmarket Research (OSA). In order to estimate the model the m hours categories of the hours offer distribution have to be chosen. To specify the discrete hours offer distribution, the hours are grouped into categories each of which contain four hours levels. As a consequence, the discrete hours distribution becomes

$$P(h = h_l) = p_l \text{ with } h_l = 4 \times l, l = 1, ..., m \tag{3.1}$$

In order to be able to identify all the probabilities, some equality restrictions are placed on probabilities of hours categories which have a low sample frequency. These restrictions are

$$\begin{aligned} p_1 = p_2 = p_3 = p_4 \\ p_6 = p_7 \\ p_{12} = p_{13} = p_{14} = p_{15} \end{aligned} \tag{3.2}$$

The value of m is chosen to be 15 in which case the maximum number of hours with a positive probability is 60, which coincides with the largest number of hours observed in the sample. The vector of individual characteristics X which appears in the utility function (2.8) consists of a constant (X_1 with parameter δ_1), the logarithm of the family size (X_2 with parameter δ_2) and a dummy indicator for the number of children with age below 6 (X_3 with parameter δ_3). The latter two are characteristics of which it is reasonable to assume that they affect the participation decision through the preferences, i.e. they affect the reservation utility level. The vector of characteristics x in the wage offer distribution consists of age variables to approximate the age-earnings profile and of education dummies as an approximation for human capital. To be more precise, x_1 is the constant term with parameter η_1, x_2 and x_3 are the logarithm of age/17 and its square, respectively, with paremeters η_2 and η_3, where the division by 17 is just a matter of normalisation, and x_4, x_5, x_6, x_7 with parameters $\eta_4 - \eta_7$ are education dummies, with x_4 the lowest level of education, x_5 is the next to the lowest level etc.

As a point of departure the model is estimated with a linear budget constraint, whereas the parameter λ, representing the average number of job offers according to the Poisson distribution, does not depend on individual characteristics, which is also the case in the studies by Tummers and Woittiez (1991) and Van Soest, Woittiez and Kapteyn (1990). Table 3.1 shows the estimation results as well as estimates of the standard errors. The parameter estimates of log-family size and the number of children with age below six, $\hat{\delta}_2$ and $\hat{\delta}_3$ respectively, have a strong positive effect on the reservation utility level. Rather high seems to be the estimate $\hat{\lambda} = 36.7$ of the Poisson distribution, indicating that the individuals in the sample are not that restricted. To compare, in Tummers and Woittiez (1991) the fixed maximum number of job offers in their binomial distribution was set equal to 10. The estimate has a sizeable standard error, however. From the estimates of the hours offer probabilities it can be seen that there are peaks at the numbers of hours of 20, 32 and 40, which can also be found back in the empirical distribution of labour supply. The age-earnings profile takes on its maximum value at the age of 33.

Having obtained parameter estimates it is possible to simulate the distribution of hours. The simulated hours frequencies can be compared with the observed hours frequencies. For each individual, a random preference parameter e and a number of job offers n is drawn form their assumed distributions. Then n wage-hours pairs are drawn, the utility levels are calculated and the highest utility level is compared with the utility of non-working to make the participation decision. This procedure is repeated 10 times and the resulting frequencies can be found in table 3.2. The second column in table 3.2 shows the observed frequencies and the third column shows the simulated frequencies. The participation decision is predicted well and the peaks at 20, 32 and 40 hours a week are predicted by the model.

Given the values of the parameter estimates it is possible to simulate the desired number of working hours, i.e. the number of working hours the individual would have chosen if she were not restricted in hours, which is the tangency point of the indifference curve and the budget constraint. Then we can simulate the frequency distribution of desired hours. In case of a linear budget constraint the utility maximizing number of hours of utility function (2.8) is h with

$$h = 0 \quad \text{if } h^* \leq 0 \tag{3.3}$$

$$= h^* \quad \text{if } h^* > 0 \tag{3.4}$$

$$h^* = \beta\mu + \gamma w + X\delta + e \tag{3.5}$$

The simulation procedure is as follows. Draw a random preference parameter e and a number of job offers n. As the individual is not restricted in her working hours the only characteristic of a job that counts is the wage rate. Draw n wage rates and choose the highest. Calculate h^* in (3.4) and make the participation decision according to (3.2) and (3.3). Count the frequencies at which the hours occur. The results are in the fourth column of table 3.2. We can see that desired participation is somewhat higher than the actual participation: the frequency of observed participation is 0.390, whereas the frequency of desired participation is 0.473. This suggests that there is involuntary unemployment. Also, we see that the desired participation at 40 hours a week is about three times smaller than the actual participation at 40 hours a week. For positive hours, the hours distributions are plotted in the figures 3.1 and 3.2. In figure 3.1 we see the sample distribution and the distribution of simulated hours. In figure 3.2 the sample distribution can be compared with the distribution of desired hours. The distribution of desired hours clearly does not match the sample distribution. The peaks at the values of 20, 32 and 40 are not present in the distribution of desired hours.

So far, the parameter λ of the Poisson distribution which influences the number of job offers received by individuals has been the same for everybody. However, there are good reasons to assume that the number of job offers received by the individuals may differs across individuals. Young persons may get more job offers than older persons. The number of job offers may be different for workers who work in different sections of the economy. Different levels of education imply different kinds of jobs and the hiring procedures for higher educated are usually not the same as those for individuals with a low level of education. Therefore, the Poisson parameter has been made dependent on individual characteristics:

$$\lambda_i = \exp(\theta' z_i), i = 1, ..., N \tag{3.6}$$

The vector z_i contains the individual characteristics. The characteristics which are included are the constant term with parameter θ_1, an age variable with parameter θ_2, dummy variables which indicate the type of education (θ_3 and θ_4) and the level of education (parameters $\theta_5 - \theta_8$). Three types of education are distinguished: non-technical and non-commercial type of education, indicated by secl in table 3.3 (parameter θ_3), semi-technical and semi-commercial type of education (sec2, θ_4), and technical and commercial type of education for which no dummy variable is included. The esimation results are in table 3.3. Before considering the parameter estimates, the values of the log-likelihood functions of the specifications with and without a characteristic dependent Poisson parameter are compared. The value of the likelihood ratio test statistic to test the nullhypothesis that λ is independent of characteristics ($\theta_2 = \theta_3 = ... = \theta_8 = 0$) is 83.58, which is well above the critical value at the 5% level of 14.07.

Looking at the estimates of the utility parameters it can be seen that there are large increases in the (absolute) values of the estimates, including that of the standard deviation of the random taste parameter, as compared to the estimates of the invariant

Poisson parameter model in table 3.1. Comparing the estimates of the parameters in θ with their standard errors we see that the age variable has a negative and significant effect, the dummy indicators for the semi-technical and semi-commercial type of education are positive and significant. The signs of the education dummy parameters are negative which indicates highest level of education has a higher Poisson parameter than the lower four levels of education. However, only the dummy for the second level is significant.

The distribution of hours is simulated in order to see how well the model tracks the empirical distribution. The simulated frequencies are in table 3.4. The results are comparable to those in table 3.2. In the last column of table 3.4 are the desired frequencies, i.e. the frequencies of the number of hours which would have been chosen according to the estimates of the utility parameters if the individual were not restricted in the choice of hours. There is a large proportion of agents which is willing to work more than 60 hours a week. This is largely the result of the large variance of the unobserved taste parameter. Again, the hours distributions are plotted. Figure 3.3 shows the sample distribution and the distribution of simulated hours and figure 3.4 shows the sample distribution along with the distribution of desired hours. The distribution of simulated hours matches the sample distribution very well. The distribution of desired hours is that flat that it almost appears as a straight line in the figure.

Until now, the following conclusions can be drawn. From the significance of the likelihood ratio test statistic it becomes clear that dependence of the distribution of the number of job offers on individual characteristics cannot be ignored, as was done in Tummers and Woittiez (1991) and Van Soest, Woittiez and Kapteyn (1990). At the same time, however, we see that if the parameter λ is made dependent on relevant individual characteristics, preferences seem to play no role anymore. The distribution of desired hours becomes very flat. This may of course be the result of the fact that demand side restrictions play such an important role on the labour market that they fully determine the behaviour of individuals. A different explanation for the phenomenon is that once the Poisson distribution has been made dependent on individual characteristics, there is simply not enough information in the data set to trace down the underlying preference structure. Furthermore, although it is possible to interprete the parameter estimates of the characteristics in λ qualitatively, it is difficult to give an interpretation to their value. In the first model for example, the estimates of which are in table 3.1, we found an estimate of λ of about 37 which, in the context of this model and ignoring the standard error for the moment, would mean that each individual on average would have obtained 37 job offers. But as the model is static, the interpretation of this number is unclear as it has no time dimension. This problem would be solved if a dynamic model of sequential search would be formulated, in which data on unemployment duration would provide additional information, both to estimate and to interprete the parameters of the number of job offer distribution and the parameters of the utility function. This approach is followed in Bloemen (1992).

We now drop the assumption that the budget constraint is linear. A progressive tax system causes the net wage rate and the number of hours to be negatively related in the budget constraint. Although a fully structural treatment of a system of labour income taxes is in principle implementable in the model, we abstain form it here because of its rather heavy computational burden. Moffit (1984) proposed to formulate the wage rate as a second order polynomial in the number of working hours. The advantage of this approach, over the introduction of a fully specified tax system, is that we can actually test for the dependence of net wages on the number of working hours.

The wage equation is extended by introducing hours.

$$\ln w = \eta' x + \tau_1 h + \tau_2 h^2 + v \tag{3.7}$$

where w is the net wage rate, x is a vector of individual characteristics and v is again a normally distributed random variable. The wage equation in (2.3) has been extended with a term which is linear in the number of working hours and a term which is quadratic in the number of working hours.

There is another reason why wages may depend on hours which is interesting to mention in this context. At institutionally determined numbers of hours like 20, 32 and 40, the offered wages may be higher for given individual characteristics and therefore hours restrictions need not be the only explanation for observing peak levels. To capture this possible relation between wages and hours in the model, dummy variables could be taken up in the wage equation. However, inspection of the data led us to abstain from it because no such relation appears to be present. Therefore, we shall assume from now on that the hours terms in the wage equation represent the tax system. The gross wage rate, w_G, is given by

$$w_G = \exp(\eta' x + v) \tag{3.8}$$

and the relation between the gross and the net wage rate is

$$w = (1 - \tau(h)) w_G \tag{3.9}$$

where $\tau(h)$ is the marginal tax rate which should be between zero and one and which is non-increasing in h for a given wage rate if the tax system is progressive. From (3.6), (3.7) and (3.8) we derive:

$$0 < \tau(h) < 1 \quad \text{if} \quad \tau_1 h + \tau_2 h^2 < 0 \tag{3.10}$$

$$\tau'(h) < 0 \quad \text{if} \quad \tau_1 + 2\tau_2 h < 0 \tag{3.11}$$

From the parameter estimates it can be checked whether these conditions are satisfied, i.e. it can be checked whether our assumption that the hours terms in the wage equation mainly represent the tax system is fulfilled.

The parameter estimates are given in table 3.5. If the estimates of the utility parameters are compared with the estimates of the basic model in table 3.1, it can be noticed that in the present model preferences play a more pronounced role. The estimate of the standard deviation of the random preference parameter has decreased substantially. The parameter estimate of the number of job offers is also reduced. There is a striking difference in the estimates of the hours offer probabilities, especially of those for the hours categories above 40 hours a week. In the basic model, there was a close relation between the observed frequencies of hours and these probabilities. The explanation for the low frequency of hours above 40 was that these values of hours are hardly offered. In table 3.5 it can be seen that according to the present model the probability of receiving hours levels of 44 or higher is not that low at all. However, the marginal increase in income as a result of working an additional hour is apparently that low as compared to the effect on the marginal utility of leisure that the individuals are in general not willing to supply these high hours levels.

Looking at the estimates of τ_1 and τ_2 it can be observed that τ_1 is positive but insignificant and that τ_2 is significantly negative. Checking relations (3.9) and (3.10) it follows that (3.9) is satisfied if $h > 5.7$ and relation (3.10) is satisfied for $h > 2.9$. This, together with the insignificance of τ_1, is in accordance with our interpretation of the hours terms.

The likelihood ratio test statistic to test the hypothesis $\tau_1 = \tau_2 = 0$ has the value 16.596. The critical value at the 5% level is 5.991, which means that the hypothesis is rejected.

The simulation results in table 3.2, 3.4 and 3.6 and the graphs in the figures 3.1, 3.2 and 3.3 provide an informal way of testing the model. To formalize the testing of the model the chi-square test statistic of Andrews (1988) can be calculated. As the aim of the testing procedure is to test the predictive power of the model, only the values of the endogenous hours variable are categorized into cells. Andrews' test statistic is calculated using three different partitions of the hours variable. Partition 1 is the most refined and coincides with the catogorisation of the hours in the simulation studies in tables 3.2, 3.4 and 3.6. In partition 2 the values of the hours have been classified according to the restrictions which have been imposed on the probabilities of the hours offer distribution. Partition 3 classifies hours in only two different groups i.e. positive and non-positive hours. The test statistic calculated with partition 3 can be used to test the predictive power of the model with respect to the participation decision. The values of the test statistic are in table 3.7. It is clear that all of the three model specifications are rejected by the three test statistics.

Estimation experiment with both an hours dependent wage equation and an individual specific Poisson parameter gave similar results as the results in table 3.3, i.e. a flat utility function.

4 Conclusions

In this paper a static model of labour supply with job offer restrictions has been formulated. A job, as it is offered by an employer to an individual, consists of both an hours component and a wage component, thereby linking the standard job search model with the static model of labour supply with hours restrictions. Because of the structure of the model, the parameters of the wage distribution and the hours distribution have been estimated simultaneously. The number of job offers has been assumed to be Poisson distributed and the parameter of the Poisson distribution has been made dependent on relevant individual characteristics to examine their effect on the average number of job offers. The results of the likelihood ratio test indicate the significance of the set of individual characteristics in the Poisson distribution. The result of the introduction of the individual characteristics in the Poisson distribution is that the parameters of the underlying utility specification cannot be traced down anymore. That is, the utility function becomes a flat and approximately uniform random function. This suggests that the available data provide too little information to obtain sensible estimates of the utility parameters. Although the simulated hours distribution in this type of model fits the labour supply data better than in the neoclassical model, as argued in Van Soest, Woittiez and Kapteyn (1990), this is mainly the result of the discrete specification of the hours offer distribution.

We have pleaded for the introduction of a time dimension into the model by formulating a sequential job search model in which duration data provide additional information in the estimation and interpretation of the model parameters. This idea is worked out in Bloemen (1992).

Estimation results of a model specification in which the wage equation contains the number of weekly working hours indicate the significance of the presence of working hours in the equation. Moreover, the estimation results are consistent with the interpretation that working hours arise in the wage equation as a result of the tax system. The estimates of this specification suggest that the fact that empirical frequencies of weekly working hours above 40 are low, is not mainly the result of low offer probabilities, as was the case in previous specifications, but is the consequence of a low marginal increase in income of working an additional hour as compared to the marginal utility of leisure at high hours levels.

Simulation experiments in which the simulated hours distribution, as generated by the model, was compared to the empirical hours distribution show that the model predicts participation and various peaks in the hours distribution well. However, a formal testing procedure rejects the hypothesis that the simulated data and the observed data have the same distribution.

TABLE 3.1 PARAMETER ESTIMATES

Parameters	Estimates	Standard errors
β	-0.0287	0.00688
γ	6.473	1.605
δ_1 (const)	18.936	9.561
δ_2 (log fs)	-56.289	10.447
δ_3 (# child<6)	-27.231	7.386
σ_e	32.616	5.246
λ	36.662	32.260
σ_v	0.460	0.0596
η_1 (const)	1.445	0.290
η_2 (log(age/17))	1.368	0.236
η_3 $(\log(age/17))^2$	-1.019	0.169
η_4 (educ1)	-0.484	0.0699
η_5 (educ2)	-0.451	0.0685
η_6 (educ3)	-0.378	0.0624
η_7 (educ4)	-0.116	0.0678
$p_1 = p_2 = p_3 = p_4$	0.0743	0.00950
p_5	0.137	0.0202
$p_6 = p_7$	0.0511	0.00848
p_8	0.117	0.0177
p_9	0.0602	0.0134
p_{10}	0.232	0.0283
p_{11}	0.0323	0.0102
$p_{12} = p_{13} = p_{14} = p_{15}$	0.00556	0.00242

Log-likelihood value: -2002.4699

TABLE 3.2 SIMULATED HOURS FREQUENCIES

hours	Empirical frequencies	Simulated frequencies	Desired frequencies
0 (i.e. non-working)	0.610	0.609	0.527
4	0.0153	0.0200	0.0321
8	0.0318	0.0245	0.0316
12	0.0236	0.0232	0.0311
16	0.0259	0.0249	0.0306
20	0.0518	0.0502	0.0294
24	0.0318	0.0218	0.0283
28	0.00942	0.0235	0.0270
32	0.0495	0.0515	0.0255
36	0.0259	0.0253	0.0242
40	0.101	0.106	0.0227
44	0.0141	0.00132	0.0213
48	0.00353	0.00165	0.0197
52	0.00471	0.00177	0.0179
56	0.000	0.00188	0.0164
60	0.00118	0.00200	0.0147
> 60			0.100

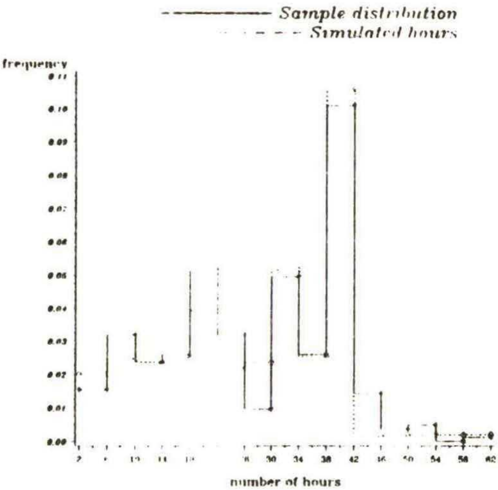

Figure 3.1 Distribution of working hours per week

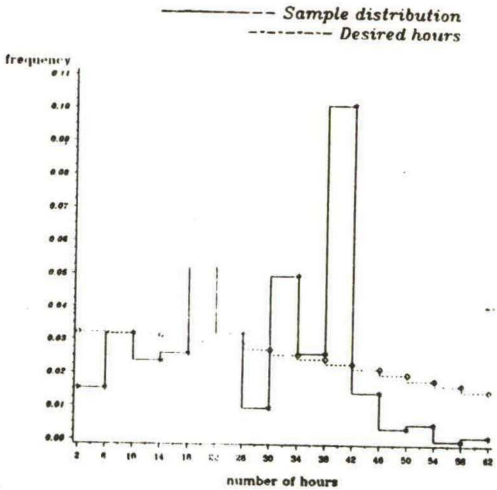

Figure 3.2 Distribution of working hours per week

TABLE 3.3 PARAMETER ESTIMATES WITH VARIATION IN λ

Parameters	Estimates	Standard errors
β	−0.163	0.319
γ	22.613	47.508
δ_1 (const)	409.473	739.121
δ_2 (log fs)	−421.260	820.003
δ_3 (# child<6)	−264.451	523.084
σ_e	248.687	484.629
θ_1 (const)	3.759	0.545
θ_2 (log(age/17))	−3.378	0.317
θ_3 (sec1)	1.417	1.427
θ_4 (sec2)	0.397	0.165
θ_5 (educ1)	−0.568	0.525
θ_6 (educ2)	−0.970	0.515
θ_7 (educ3)	−0.445	0.483
θ_8 (educ4)	−0.119	0.506
σ_v	0.265	0.00113
η_1 (const)	1.857	0.119
η_2 (log(age/17))	1.912	0.259
η_3 $(\log(age/17))^2$	−1.060	0.197
η_4 (educ1)	−0.397	0.0889
η_5 (educ2)	−0.288	0.0839
η_6 (educ3)	−0.279	0.0764
η_7 (educ4)	−0.0962	0.0824
$p_1 = p_2 = p_3 = p_4$	0.117	0.0120
p_5	0.162	0.0244
$p_6 = p_7$	0.0477	0.00857
p_8	0.0888	0.0154
p_9	0.0386	0.00918
p_{10}	0.125	0.0213
p_{11}	0.0148	0.00495
$p_{12} = p_{13} = p_{14} = p_{15}$	0.00194	0.000802

Log-likelihood value: -1960.6767

TABLE 3.4 SIMULATED HOURS FREQUENCIES

hours	Empirical frequencies	Simulated frequencies	Desired frequencies
0 (i.e. non-working)	0.610	0.603	0.484
4	0.0153	0.0177	0.00441
8	0.0318	0.0216	0.00443
12	0.0236	0.0260	0.00434
16	0.0259	0.0315	0.00432
20	0.0518	0.0529	0.00427
24	0.0318	0.0188	0.00437
28	0.00942	0.0228	0.00412
32	0.0495	0.0509	0.00439
36	0.0259	0.0272	0.00451
40	0.101	0.104	0.00426
44	0.0141	0.0144	0.00432
48	0.00353	0.00206	0.00432
52	0.00471	0.00221	0.00438
56	0.000	0.00241	0.00441
60	0.00118	0.00252	0.00446
> 60			0.450

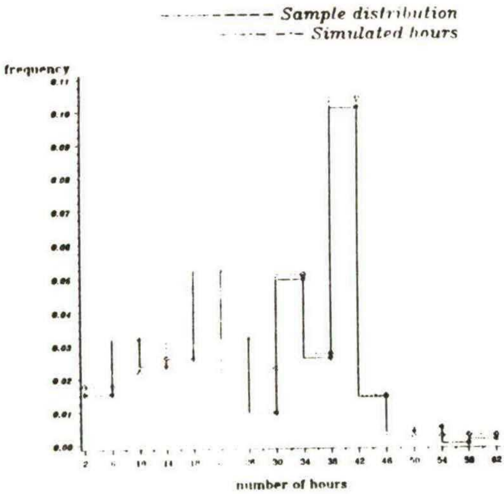

Figure 3.3 Distribution of working hours per week

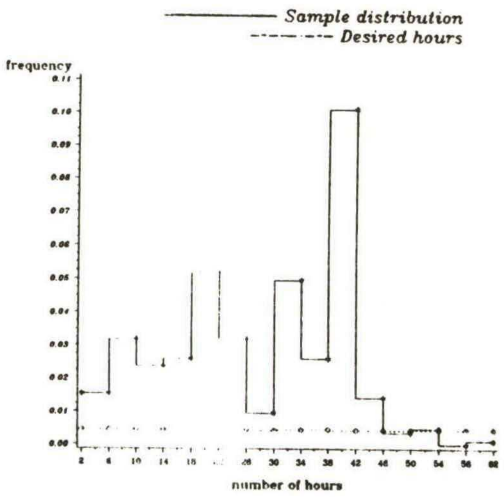

Figure 3.4 Distribution of working hours per week

TABLE 3.5 PARAMETER ESTIMATES,
MODEL WITH HOURS DEPENDENT WAGES

Parameters	Estimates	Standard errors
β	−0.0172	0.00476
γ	4.185	1.201
δ_1 (const)	14.670	5.664
δ_2 (log fs)	−31.568	7.887
δ_3 (# child<6)	−15.973	5.077
σ_e	16.675	4.458
λ	17.578	10.952
σ_v	0.356	0.0362
η_1 (const)	2.218	0.187
η_2 (log(age/17))	1.388	0.242
η_3 (log(age/17))^2	−1.388	0.173
η_4 (educ1)	−0.495	0.0750
η_5 (educ2)	−0.460	0.0719
η_6 (educ3)	−0.359	0.0674
η_7 (educ4)	−0.125	0.0721
τ_1	0.00208	0.00652
τ_2	−0.000362	0.000122
$p_1 = p_2 = p_3 = p_4$	0.00760	0.00472
p_5	0.0210	0.0120
$p_6 = p_7$	0.0121	0.00656
p_8	0.0504	0.0235
p_9	0.0433	0.0184
p_{10}	0.312	0.0952
p_{11}	0.0923	0.0299
$p_{12} = p_{13} = p_{14} = p_{15}$	0.107	0.0451

Log-likelihood value: -1985.8735

TABLE 3.6 SIMULATED HOURS FREQUENCIES, HOURS DEPENDENT WAGES

hours	Empirical frequencies	Simulated frequencies	Desired frequencies
0 (i.e. non-working)	0.610	0.600	0.137
4	0.0153	0.0251	0.0382
8	0.0318	0.0257	0.0498
12	0.0236	0.0250	0.0627
16	0.0259	0.0227	0.0860
20	0.0518	0.0537	0.102
24	0.0318	0.0247	0.107
28	0.00942	0.0183	0.113
32	0.0495	0.0514	0.102
36	0.0259	0.0269	0.0999
40	0.101	0.103	0.0729
44	0.0141	0.00142	0.0219
48	0.00353	0.00640	0.00612
52	0.00471	0.00199	0.00188
56	0.000	0.000599	0.000234
60	0.00118	0.000110	0.000
> 60			0.000

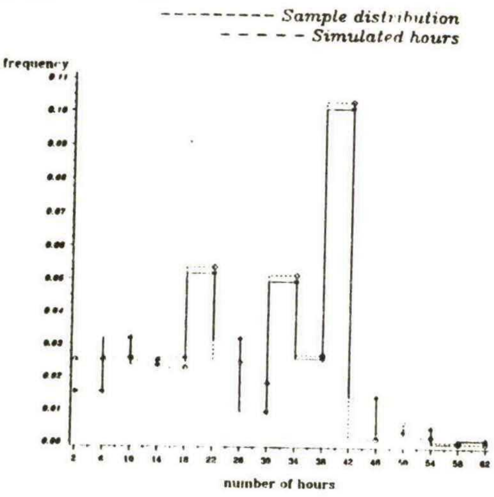

Figure 3.5 Distribution of working hours per week

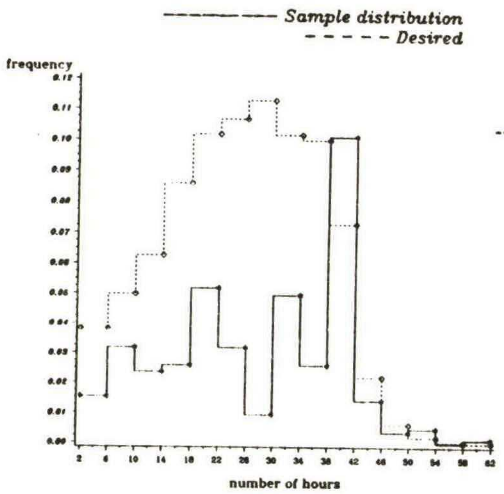

Figure 3.6 Distribution of working hours per week

TABLE 3.7 ANDREWS' CHI-SQUARE TEST STATISTIC

chi-square statistic	partition 1	partition 2	partition 3
fixed λ model	395.460	47.466	33.534
variable λ model	269.233	39.481	19.062
hours dependent wages	216.504	49.494	34.337
critical value at 5% level	24.996	15.507	3.841

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