Female labour supply in Spain: The importance of behavioural assumptions and unobserved heterogeneity specification

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Abstract

We estimate four models of female labour supply using a Spanish sample of married women from 1994, taking into account the complete form of the individual's budget set. The models differ in the hypotheses relating to the presence of optimisation errors and/or the way non-workers contribute to the likelihood function. According to the results, the effects of wages and non-labour income on the labour supply of Spanish married women depend on the specification used. The model which has both preference and optimisation errors and allows for both voluntarily and involuntarily unemployed females desiring to participate seems to better fit the evidence for Spanish married women.

I.INTRODUCTION

The importance of specification issues in estimating labour supply models is well known[1]. Not only econometric aspects such as sample selection problems related to wages, the fact that the endogenous variable is censored, or the distributional assumptions[2], but also other specification aspects are relevant. In that sense, the empirical literature has taken note of the importance of the characteristics of the budget set (tax system)[3], the specification of different models for the participation decision and the hours equation[4], the consideration of restrictions on labour supply[5], or the analysis of household labour supply decisions rather than individual ones[6].

In this paper we put forward evidence of the importance of modelling how the process of forming the observed decisions can take place. In particular, we estimate different models for the labour supply decisions of Spanish married women which differ in the assumptions about how the relationship between desired and observed participation and hours decisions are specified[7]. Additionally, we also try to shed some light on the impact of considering two different types of unobserved heterogeneity (preference and optimisation errors) against the case with only one source. The evidence, based on the estimated coefficients, on the explanatory power of the models and on the estimated wage and income elasticities, depends on these assumptions.

The models are estimated using the information contained in the 1994 and 1995 waves of the European Household Panel for Spain and they have a more realistic specification of the budget set than previous studies of the Spanish case, in terms of considering all the tax brackets[8] and allowing the possibility of choosing between separate and joint taxation as was possible in Spain in the period considered[9]. The estimation procedure corresponds to what is known in the literature as Hausman´s approach[10], assuming a linear specification for the labour supply equation.

The rest of the paper is organised as follows. In Section 2 we present the main assumptions regarding individual preferences, budget constraints and the process of observing an individual as a non-worker or working a particular number of hours. The econometric specification is outlined in Section 3. In Section 4 we describe the data and the main characteristics of the Spanish tax system and we present the maximum likelihood estimates. In Section 5 wage and income elasticities are calculated and Section 6 sets out conclusions.

II. THE MODEL

We specify a static neoclassical labour supply model which incorporates the main characteristics of the Spanish tax system. The desired working time is assumed to be linear in wage and non-labour income. This latter variable includes the husband's income because we assume that the wife's labour behaviour is independent of that of her husband's. Besides those two explanatory variables, personal and household characteristics may contribute to explain female working time. Finally, we add an unobserved heterogeneity random component in the utility function, which explains why two individuals with the same economic and socio-demographic characteristics can be working for a different number of hours per week.

Consumption and hours of work are determined so as to maximise the individual's utility function subject to a piecewise-linear budget constraint:

$$
\begin{aligned}
& max_{c,h} \quad U(c,h;\boldsymbol{X},e) \\
& s.a. \quad c = w_1 h + y_1 \quad if \quad 0 \le h \le H_1 \\
& \qquad c = w_2 h + y_2 \quad if \quad H_1 < h \le H_2 \\
& \qquad \ldots \\
& \qquad c = w_K h + y_K \quad if \quad H_{K-1} < h \le T
\end{aligned}
\qquad (1)
$$

where U denotes utility, c is consumption expenditure, h is weekly working time, $\boldsymbol{X}$ is a vector of socio-demographic variables which may affect individual tastes, e is the preference random term, w_k is the after-tax hourly wage [$w_k = w(1-t_k)$, t_k being the marginal tax rate for segment k and w the gross wage], y_k, which is usually termed virtual income, is the intercept we would obtain if the segment k were extended to zero hours of work, H_k is the upper kink point for segment *k* and *T* is the total time endowment. The subscripts referring to individuals are omitted in order to simplify the notation.

Thus, the budget constraint consists of a number, *K*, of segments, each one defined by its net wage, its virtual income, and the kink points. Virtual income for tax bracket *k* is given by the following expression:

$$y_K = y + w(t_2 - t_1)H_1 + \ldots + w(t_K - t_{K-1})H_{K-1} \qquad (2)$$

where *y* is the net non-labour income the wife receives when she does not work.

The specification of the budget set requires the calculation of the kink points, that is, the values of working time in which there is a change in the marginal tax rate. We then obtain the after-tax earnings at each kink and calculate the marginal tax rate of each segment by assuming that the budget set is linear between two consecutive kink points and that the marginal tax rate of a particular segment is greater than or equal to that of the previous one. In fact, the fiscal deductions and the possibility for married couples to choose either joint or separate taxation may produce nonconvexities in the tax schedule but, given the large number of tax brackets in the Spanish system, this linearization should not generate any special distortion in the results.

We assume a utility function which yields a linear labour supply with the following expression[11]:

$$
\begin{aligned}
&h^s = 0 && \text{if} \quad g_1 + e \leq 0 \\
&h^s = g_k + e && \text{if} \quad H_{k-1} \leq g_k + e \leq H_k, \qquad k = 1,2,...,K \\
&h^s = H_k && \text{if} \quad g_k + e > H_k \quad y \quad g_{k+1} + e < H_k, \quad k = 1,2,...,K-1 \\
&h^s = H_K && \text{if} \quad g_K + e > H_K
\end{aligned}
\tag{3}
$$

where h^s denotes the number of desired working hours, e is the preference error, which is assumed to be normally distributed with constant variance s_p^2, and g_k is the non-random component of the labour supply:

$$g_k = a_1 w_k + a_2 y_k + \boldsymbol{bX} \tag{4}$$

where a_1, a_2 and $\boldsymbol{b}$ are parameters.

We specify four alternative models, which differ with regard to the hypothesis about the optimisation error and/or the likelihood contribution of non-workers. Model 1 considers that individuals are not always free to choose their working time, so there may be differences between the number of desired and usual hours of work and there may be involuntarily unemployed people[12]. We assume that workers always desire a positive working time, because they can stop working whenever they want. Non-workers, however, may be in that situation either voluntarily or involuntarily. Thus, the observed working time will be equal to:

$$
\begin{aligned}
&h^a = 0, \qquad \text{if} \quad h^s = 0 \quad \text{or} \quad h^s + u \leq 0 \\
&h^a = h^s + u, \quad \text{if} \quad h^s > 0 \quad \text{and} \quad h^s + u > 0
\end{aligned}
\qquad (5)
$$

where h^a is the actual working time, and u, the optimisation error, which is normally distributed with variance s_o^2 and is independent of the preference error e.

Model 2 assumes that there may be optimisation errors but every non-worker is voluntarily in that labour situation, i.e., both preferred and observed decisions coincide for them. The observed working time is thus given by:

$$
\begin{aligned}
&h^a = 0, \qquad \text{if} \quad h^s = 0 \\
&h^a = h^s + u, \quad \text{if} \quad h^s > 0 \quad \text{and} \quad h^s + u > 0
\end{aligned}
\qquad (6)
$$

The main hypothesis of Model 3 is that there are no differences between the desired and usual working time ($h^a = h^s$), so there are no optimisation errors.

Finally, the database used in the estimation allows us to know whether non-working women are involuntarily unemployed or non-participants. The three previous models do not use this information but Model 4 does. Specifically, this model assumes that women classified as non-participants in the survey are not in the labour force, i.e., in their case desired and observed situations coincide.

III. ECONOMETRIC SPECIFICATION

Following Hausman´s approach we estimate the model by maximum likelihood taking into account the characteristics of the budget set. In this section we present the likelihood functions for the four different specifications proposed.

Model 1 assumes that there is an optimisation error and allows for involuntary unemployment. As the usual working time may be different from the desired one, we do not know the value of the latter variable. For workers, we only know that they desire to work a positive number of hours, so the probability of a woman working h^a_i hours is equal to the joint probability of desired hours being at any point on the individual's budget constraint and observed hours being equal to h^a_i:

$$Pr(h^a = h_i^a) = \sum_{k=1}^{K} Pr(h^s \in segment\ k,\ h^a = h_i^a) + \sum_{k=1}^{K} Pr(h^s = H_k, h^a = h_i^a) \tag{7}$$

The first term is the probability of observing a person working h^a_i hours per week when she desires to work along the segment *k*. Taking into account the assumptions about the labour supply function and the random terms, this probability can be written as:

$$Pr(h^s \in segment\ k, h^a = h_i^a) =$$

$$Pr\left(\frac{H_{k-1} - g_k}{s_p} \le \frac{e}{s_p} \le \frac{H_k - g_k}{s_p} \Bigg/ \frac{e+u}{(s_p^2 + s_o^2)^{1/2}} = \frac{h_i^a - g_k}{(s_p^2 + s_o^2)^{1/2}} \right) \times \tag{8}$$

$$Pr\left(\frac{e+u}{(s_p^2 + s_o^2)^{1/2}} = \frac{h_i^a - g_k}{(s_p^2 + s_o^2)^{1/2}} \right)$$

The second term is the probability of desiring to work at any kink point (H_k) and working h^a_i and is given by:

$$Pr(h^s = H_k , h^a = h_i^a) =$$

$$Pr\left[(g_k + e > H_k) \cap (g_{k+1} + e < H_k), \quad h^a = H_k + u\right] = \qquad (9)$$

$$Pr\left(\frac{H_k - g_k}{s_p} < \frac{e}{s_p} < \frac{H_k - g_{k+1}}{s_p} \right) Pr\left(\frac{n}{s_o} = \frac{h_i^a - H_k}{s_o} \right)$$

The contribution to the likelihood of a non-worker is equal to the probability that she does not desire to work or she wants to work but has not found a job:

$$Pr(h^a = 0) =$$

$$Pr(h^s = 0) + \sum_{k=1}^{K} Pr(h^s \in segment\ k, h^a = 0) + \sum_{k=1}^{K} Pr(h^s = H_k , h^a = 0) \qquad (10)$$

where the terms of the previous equation have the following expressions:

$$Pr(h^s = 0) = Pr(g_1 + e \leq 0) = Pr\left(\frac{e}{s_p} \leq \frac{-g_1}{s_p} \right) \qquad (11.a)$$

$$Pr(h^s \in segment\ k, h^a = 0) =$$

$$Pr\left(\frac{H_{k-1} - g_k}{s_p} \leq \frac{e}{s_p} \leq \frac{H_k - g_k}{s_p} , \frac{e + n}{(s_p^2 + s_o^2)^{1/2}} \leq \frac{-g_k}{(s_p^2 + s_o^2)^{1/2}} \right) \qquad (11.b)$$

$$Pr(h^s = H_k, h^a = 0) =$$

$$Pr\left(\frac{H_k - g_k}{s_p} < \frac{e}{s_p} < \frac{H_k - g_{k+1}}{s_p} \right) Pr\left(\frac{n}{s_o} \le \frac{-H_k}{s_o} \right) \tag{11.c}$$

The log-likelihood function is constructed from the equations (7)-(11) and takes the form:

$$Log\, L = \sum_i d_i \, log\left[Pr(h^a = h_i^a)\right] + (1 - d_i)\, log\left[Pr\,(h^a = 0)\right] \tag{12}$$

where d_i is a dummy variable which takes the value of one when the individual is working and zero otherwise. Maximising the log-likelihood function produces estimates of the labour supply coefficients and the standard deviation of both random terms. In fact, equation (12) represents the general form of the likelihood function for our four models, which differ in the way the contributions of both workers and non-workers are defined.

Model 2 assumes that there are no involuntarily unemployed people. The likelihood function is the same as equation (12), but in this case the probability of being a non-worker is equal to the probability of being a non-participant:

$$Pr(h^a = 0) = Pr(h^s = 0) = Pr(g_1 + e \le 0) = Pr\left(\frac{e}{s_p} \le \frac{-g_1}{s_p} \right) \tag{13}$$

In Model 3 we do not include optimisation errors, so the actual working time is always equal to the desired one. The construction of the likelihood function is simpler than the previous ones. The probability of observing zero hours of work is the same as in Model 2 [equation (13)]. On the other hand, the probability of working $h^a{}_i$ hours, where $h^a{}_i$ is located on segment *k*, is equal to the probability of desiring that value of working time:

$$Pr(h^a = h_i^a) = Pr(h^s = h_i^a) = Pr\left(\frac{e}{s_p} = \frac{h_i^a - g_k}{s_p} \right) \qquad (14)$$

Finally, Model 4 differs from the first one in the specification of the probability of non-working. According to Model 1, every non-worker may be voluntarily or involuntarily unemployed. Model 4 uses the information provided by the survey about the labour situation of these women. It assumes that those females who state that they are non-participants do not belong to the labour force, so their likelihood contribution is given by equation (13). Therefore, we have three types of contributions to the likelihood function, that of workers, that of involuntarily unemployed and that of voluntarily unemployed.

By comparing the estimation results for these four models we can evaluate the importance of the behavioural assumptions and the role of the error terms when estimating a labour supply model for married women in Spain, both in terms of the explanatory power of the models and in terms of its influence on the estimated coefficients, in particular those relevant in economic terms, such as the income and wage elasticities.

IV. EMPIRICAL ESTIMATION

The estimation of the four models is based on a sample of married women drawn in 1994. In the first subsection, we describe the 1994 Spanish income tax focusing on the characteristics we have taken into account when specifying the budget constraint. In addition, we comment the sample selection and the variables used in the estimation. The second subsection presents the results of the estimation of the four models mentioned above.

Data and Spanish income tax system in 1994

Spanish income tax, known as IRPF (Impuesto sobre la Renta de las Personas Físicas), in 1994 is a piecewise linear function of taxable income, with the marginal tax rates increasing from 0% to 56%. Married couples have the possibility of complying with their fiscal duties jointly or separately. The number of tax brackets are eighteen or seventeen depending on the regime chosen.

Taxable income is the sum of gross labour and non-labour earnings minus some quantities that can be deducted before applying the tax rates, such as Social Security payments. After calculating the taxable income, the individual has to apply the table of marginal tax rates, and from the amount obtained he/she can make certain deductions. We have considered deductions for children, parents, wage income and house rent. There are also other fiscal deductions, for example, housing allowances, but we do not have enough information to take account these into. Some of these deductions have limits which may introduce nonconvexities in the budget set. As we have already mentioned, when this happens we use a convex approximation, by assuming the linearity of the budget set between two consecutive kink points and establishing that the marginal tax rate in a segment is always greater or equal to that of the previous one.

Moreover, married couples can choose either to pay tax jointly or individually and they are likely to opt for the regime which implies the least amount of tax payment. We assume that those couples where the wife does not work pay tax jointly, because this is usually the best option for them, and when the woman works, we calculate the taxes the couple would pay under each regime and we assigned them the most favourable one[13].

The data we use for estimating the four models come from the Spanish section of the European Household Panel which is carried out in Spain by the Instituto Nacional de Estadística. It is collected at the household level and provides information about personal and household characteristics. We have chosen it because it contains very detailed data about income, and thus allows for a better approximation of the individual's budget set than other surveys available for Spain.

The empirical analysis is based on a sample of married women who are living with their husbands and are not the household head. The family may also be made up of children, parents and parents-in-law. We have restricted the analysis to couples between 16 and 65 years old. We have eliminated observations where any member had changed to a new household from 1994 to 1995, the wife was self-employed or there was missing data. These selection rules leave us with a sample size of 2586 observations of whom 576 are working.

The dependent variable is the usual weekly working time. Turning to the explanatory factors, we include the net wage and virtual income. The wage is measured using information about monthly earnings and weekly working hours. The virtual income is calculated as previously explained [see equation (2)]. For its calculation we need the net nonlabour income the woman would have if she did not work and we assume that it consists of the net husband's labour earnings and the net family nonlabour earnings .

Labour supply is also influenced by a vector of socio-demographic variables (***X***). We assume that individual's age and health may influence labour supply decisions. This latter variable is equal to one for those women who are in good health and this is likely to have a positive effect on labour supply. Family characteristics included are the number of children under 14, the number of members over 14 and a dummy variable which takes the value one when the woman looks after children or adults. Moreover, we incorporate the monthly payments due to mortgage loans as a way of capturing its effect through the budget set, since we do not have enough information to calculate housing allowances but we think the mortgage payments may increase the female labour supply. Finally, we have also incorporated regional dummies.

Results

In the estimation we have taken into account the fact that the wage is not observed for non-workers and it may be correlated with the labour supply random term[14]. To deal with these problems we substitute wages (observed or not) by its prediction, so the estimation has been carried out in three stages. First of all, we fit a probit model for the probability of working. Secondly, we estimate a wage equation with the subsample of workers and incorporating the inverse Mills ratio as an explanatory variable. The dependent variable in this equation is the (log) gross hourly earnings. We then calculate net wages and virtual incomes for each woman using the predicted gross wage. Finally, we estimate the female labour supply model by maximum likelihood. The estimates for the probit and the wage equation are shown in Tables A2 and A3 in the Appendix.

In Table 1 we report the maximum likelihood estimates of Model 1, which has two random terms and allows for involuntary unemployment. We base our comments on the effects of the explanatory variables on the estimation which considers the most preferable tax regime. Wages have a positive effect on the desired labour supply whereas nonlabour income has a negative one, being both significantly different from zero. Therefore, these coefficients satisfy the Slutsky condition. Female age increases labour supply at a decreasing rate and mortgage payments also have a positive influence. On the contrary, but as expected, family characteristics –number of children under 14 and the dummy for children/adult care- decrease the labour supply of married women. This latter result confirms the importance of housework in explaining female labour behaviour. With regard to regional variables, women living in the East desire longer working hours than the rest.

(TABLE 1)

The standard deviations of both random terms are significant, being greater that of the preference error. The variation of the observed working time is therefore better explained by differences in individual tastes than by other types of reasons[15]. On the other hand, the significance of the optimisation error highlights the existence of differences between desired and observed working hours.

When comparing the three versions of Model 1 in Table 1 we must point out the significant increase in the value of the likelihood function when estimating the model in which the most preferable tax regime for each individual is considered. That means that the behaviour of individuals is better explained by a model based on a more complete utility maximization framework, proxied by the most favourable tax regime. Consequently, the simplifications in terms of the budget set imposed by the versions corresponding to both the individual tax regime and the joint tax regime could imply inconsistent estimates, as shown, in particular, when looking at the estimates of the coefficients of the virtual income, positive in the joint tax regime version.

Table 2 presents estimates of the four models for the version in which couples choose the most favourable tax regime. The values of the likelihood function for that four models show that the first model, more general than Models 2 and 3, and with different behavioural assumptions than Model 4, better explains the labour supply decisions of Spanish females (the value of the likelihood function is about 10% higher for Model 1 than for the rest). In fact, the worst model is the simplest one (Model 3) which only considers preference errors.

When we have not taken into account the presence of involuntary unemployment (Model 2) there are important changes in the coefficients. In particular, the nonlabour income is not now significant and the wage coefficient is much smaller than that of Model 1.

(TABLE 2)

Turning to Model 3, which assumes that there is no optimisation error, the most outstanding result is that the coefficient of nonlabour income is positive and significant, contrary to the theory. However, the substitution effect is positive when the working time is under 49.7 hours per week, so a high proportion of the sample will satisfy the Slutsky condition. The rest of the results are similar to Model 2.

Model 4 distinguishes between unemployed and non-participant females. It differs from Model 1 in the specification of the likelihood contribution for non-workers. In particular, it assumes that those non-workers who are classified as non-participants are not looking for a job. Comparing the results of Models 1 and 4, we can see that, although there are no changes in the signs of the coefficients, there are differences in their values. For example, the effect of the net wage on the female labour supply is lower in Model 4 than in Model 1 and the nonlabour income is not significant in Model 4. On the other hand, health and the number of members over 14 are significantly different from zero in the latter model.

Although all the models show that labour supply decisions have a high degree of dependence on socio-demographic and economic variables and also present similar estimates for the variances of the error terms, the results show that the specification of how these decisions are made and the different role of unobserved error terms are relevant when modelling labour supply and estimating relevant parameters such as wage and income elasticities, as will be shown in the next section. In fact, the coefficient estimates of wage and income variables are higher in absolute value for Model 1 than for the rest of the models.

V. WAGE AND INCOME ELASTICITIES

The calculation of the wage and income elasticities will allow us to evaluate the responses of the female labour supply when any of those variables changes. As the budget set is piecewise linear, the labour supply is not differentiable because an increase in any explanatory factor may produce a change of segment or kink. That is the reason why prefer to obtain the elasticities by performing simulation exercises.

In the simulation, the values of the random terms are assigned to each woman in such a way that the predicted initial number of hours is the same as the observed one. For Model 1, we draw a value of the preference error for each woman, such that workers desire a positive number of hours. The optimisation error for that group is calculated as the difference between the desired and usual working time, whereas, for non-workers, we draw a value of that term satisfying the condition that the predicted number of hours cannot be positive. In Model 2 the preference error assigned to non-workers cannot yield a positive desired number of working hours. In addition, in Model 3 the preference error for workers is just the difference between the hours of work and the non-random component of the labour supply function. Finally, the procedure applied to Model 4 differs from Model 1 in that the preference error is drawn in such a way that non-participants cannot be predicted desiring to work.

The first simulation exercise analyses the effect of a 10% increase in wages on participation and hours of work. The second one considers a 10% increase in the husband's earnings, which is part of his wife's nonlabour income. In both cases we add the individual effects over the whole sample.

Table 3 presents the results for the wage elasticities of the simulations for the four models proposed, in the version which considers for each individual the most favourable taxation regime. In particular, we report the participation elasticity (which provides information about the variation in the number of participants), the elasticity of hours (which shows the change in average hours worked by participants), and the total elasticity, which is roughly the sum of the other two, for both desired and observed situations.

(TABLE 3)

According to the elasticities obtained for Model 1, wages have a positive effect on the number of women desiring to participate and on the desired number of hours conditional on participation. Given that there are a number of initial non-working women for whom the predicted number of weekly hours is very small after the increase in their wage, and as it is very unusual to observe such small values, we restrict the condition of participation to people working at least five hours a week when calculating the elasticities for the observed hours. These elasticities show more reasonable values than those obtained without this assumption. Moreover, our results are similar to those obtained in other studies applied to Spanish women. For example, García *et al*. (1989) compute a participation elasticity equal to 1.56 and the elasticity of hours conditional on work is 0.29, whereas those calculated in García *et al*. (1993) are 1.35 and 0.29, respectively. As in those studies, in our case the participation responses are geater than the working time responses.

There are important differences in the elasticities depending on the model considered. For Models 2, 3 and 4 they are considerably smaller than those of Model 1, all, in fact, being lower than one, and with the elasticity of participation smaller than that of observed hours in the case of Models 2 and 3.

With respect to the income elasticities, we analyse the effect of a 10% increase in the husband’s gross labour earnings. This variable only has an income effect on the labour supply of women who pay tax separately but, when the couple pay taxes jointly, its influence on female labour supply is more complex because the net wages can change for the first segment of the budget set. That is the reason why participation may increase, as it can be seen in Table 4, where we report the income elasticities for all the models and for both desired and observed situations.

(TABLE 4)

In general, an increase in the husband's nonlabour earnings has a negative influence on the average desired working time. However, the observed participation increases for all four models. In any case, the response of participation and hours of work is very small (always lower than one), a result frequently obtained in the empirical literature about labour supply[16]. The estimated elasticities differ very much among the four models considered in this exercise.

As was expected after looking at the differences in the estimated coefficients and the explanatory power for those four models, we also find significant differences in the estimated wage and income elasticities depending on both behavioural assumptions and the specification of different sources for unobserved heterogeneity.

VI. CONCLUSIONS

We have proposed four different specifications to explain the labour supply of married women taking into account the Spanish tax system. The models differ in the behavioural assumptions about participation and the role of preference and optimisation errors. All of them are static and have been estimated using Hausman´s approach.

Individual preferences are assumed to generate a linear labour supply and the individual's budget set is convex and consists of several segments. The four models have a random term representing unobserved factors which may affect the female's preferences towards working time and consumption. On the other hand, in three specifications we also include an optimisation error which may explain the presence of differences between observed and desired hours of work.

Model 1 assumes that there are preference and optimisation errors and involuntary unemployment in that there are women who desire to participate but who do not work due to the optimisation term. Model 2 excludes the possibility of involuntary unemployment. However, it takes account of the possibility that actual working time differs from that desired by workers. Model 3 has only a random component which represents the heterogeneity in individual preferences. Model 4 is similar to the first one in that it has two stochastic terms and assumes involuntary unemployment, but differs from Model 1 because it uses the available sample information on the classification of a non-worker as unemployed or non-participant. In particular, it considers that women who affirm that they do not want to work have a desired working time equal to zero hours.

We found that personal and family characteristics, as well as economic variables, affect the labour supply of married women. We performed simulations to calculate wage and income elasticities and obtained results showing that the former are generally larger than the latter. The comparison of the log-likelihood values allows us to conclude that Model 1 is preferred to the other three proposed. However, there is a wide variation in results depending on the specification, which points out the importance of the specification issues considered in this study when estimating labour supply models.

APPENDIX

(TABLE A1)

(TABLE A2)

(TABLE A3)

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Table 1. Maximum likelihood estimates of the labour supply (Model1)

(Dependent variable: weekly hours of work)

	Individual tax regime		Joint tax regime		Most preferable tax regime	
Variables	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Constant	-139.67	-3.253	-132.13	-3.328	-117.82	-3.297
Net wage / 100	10.500	4.409	8.155	4.131	13.971	6.127
Virtual income /10000	-2.384	-2.967	0.757	1.427	-2.380	-3.291
Mortgage payments/100	0.020	2.568	0.017	2.620	0.015	2.189
Age	4.685	2.503	4.878	2.885	2.833	1.714
Age^2 / 100	-7.798	-3.182	-7.656	-3.390	-5.729	-2.815
Health	5.414	1.402	5.378	1.643	3.526	0.974
No. members ≥ 14	-4.101	-1.842	-3.720	-2.101	-2.499	-1.232
No. children < 14	-7.181	-2.475	-5.961	-2.578	-6.490	-2.501
Children/adult care	-8.450	-1.963	-7.736	-2.059	-7.894	-1.929
Northwest	-6.234	-0.746	-3.563	-0.527	-6.644	-0.814
Northeast	8.956	1.149	7.945	1.235	8.260	1.096
Centre	-7.456	-0.908	-4.038	-0.610	-8.878	-1.108
Madrid	1.988	0.242	3.679	0.543	1.799	0.222
East	18.975	2.285	15.620	2.260	18.100	2.367
South	-0.658	-0.087	0.736	0.120	-0.952	-0.130
σ_p	47.671	4.936	39.251	4.558	44.734	6.648
σ_o	17.096	4.956	18.413	4.898	15.975	6.015
Log L	-3480.52		-3533.75		-3361.60	
Sample size			2586			

Note: Model 1 has optimisation and preference errors and allows for involuntary unemployment. Omitted dummies are: bad health, not looking after children/adult and Canary Islands.

Table 2. Maximum likelihood estimates of female labour supply

(Dependent variable: weekly hours of work)

Variables	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-val.	Coeff.	t-val.	Coeff.	t-val.	Coeff.	t-val.
Constant	-117.8	-3.30	-193.4	-4.00	-193.2	-5.21	-189.5	-3.95
Net wage/100	13.97	6.13	2.56	5.18	0.80	3.26	2.53	5.12
Virtual income/10000	-2.38	-3.29	-0.44	-0.88	1.62	2.92	-0.46	-0.93
Mortgage payments/100	0.02	2.19	0.03	3.40	0.03	4.18	0.03	3.35
Age	2.83	1.71	9.06	3.87	9.41	5.00	8.96	3.85
$Age^2/100$	-5.73	-2.82	-12.39	-4.10	-12.74	-5.36	-12.30	-4.08
Health	3.53	0.97	11.09	2.75	9.96	2.92	11.17	2.76
No. members ≥ 14	-2.50	-1.23	-6.06	-2.82	-6.49	-3.53	-6.04	-2.82
No. children < 14	-6.49	-2.50	-7.14	-2.84	-7.26	-3.29	-7.10	-2.84
Children/adult care	-7.89	-1.93	-7.53	-2.02	-8.58	-2.41	-7.64	-2.05
Northwest	-6.64	-0.81	0.82	0.12	0.79	0.12	0.85	0.12
Northeast	8.26	1.10	11.55	1.66	11.78	1.78	11.42	1.65
Centre	-8.88	-1.11	-0.77	-0.11	1.95	0.29	-0.81	-0.12
Madrid	1.80	0.22	10.67	1.42	9.55	1.36	10.51	1.41
East	18.10	2.37	19.89	2.63	18.51	2.75	19.94	2.63
South	-0.95	-0.13	3.43	0.52	4.12	0.65	3.73	0.57
σ_p	44.73	6.65	45.62	5.35	46.59	9.61	45.16	5.28
σ_o	15.98	6.02	13.90	2.98			14.02	2.96
Log L	-3361.60		-3706.38		-3755.30		-3688.61	
Sample size	2586							

Notes: The difference between Models 1 and 2 is that the first one allows for involuntary unemployment. Model 3 assumes that there are only preference errors. Model 4 assumes that non-participants do not desire to work a positive number of hours. In all models each woman is assumed to choose the most favourable taxation regime. Omitted dummies are: bad health, not looking after children/adult and Canary Islands.

Table 3. Wage elasticities

	Model 1	Model 2	Model 3	Model 4
Desired participation	0.911	0.417	0.191	0.510
Desired hours	1.299	0.153	-0.039	0.011
Total	2.328	0.575	0.151	0.522
Observed participation*	1.615	0.000	0.000	0.260
Observed hours*	0.334	0.402	0.150	0.221
Total*	2.002	0.402	0.150	0.487

*Restricting the analysis to people whose working time is at least 5 hours a week.
Notes: The same as Table 2.

Table 4. Income elasticities

	Model 1	Model 2	Model 3	Model 4
Desired participation	-0.158	0.226	0.174	0.351
Desired hours	-0.046	-0.258	-0.049	-0.372
Total	-0.204	-0.038	0.123	-0.034
Observed participation*	0.330	-0.104	0.000	0.191
Observed hours*	-0.294	0.004	0.121	-0.143
Total*	0.026	-0.100	0.121	0.045

*Restricting the analysis to people whose working time is at least 5 hours a week.
Notes: The same as Table 2.

Table A1. Descriptive statistics

Variable	Total sample (2586 observations)		Working women (576 observations)	
	Mean	Standard deviation	Mean	Standard deviation
Participation	0.223	0.416	1.000	0.000
Observed weekly hours	8.106	15.648	36.394	8.334
Net annual nonlabour income*	2038.672	1317.256	2354.126	1644.452
Predicted hourly gross wage (pts)	810.506	281.565	1009.756	396.620
Children/adult care	0.616	0.487	0.637	0.481
Health	0.667	0.471	0.800	0.400
Secondary education	0.133	0.340	0.205	0.404
Higher education	0.130	0.337	0.359	0.480
Unemployment in last 5 years	0.285	0.452	0.295	0.457
Age	42.505	10.547	38.559	7.937
No. children < 14	0.790	0.908	0.899	0.912
No. members ≥ 14	3.014	1.164	2.773	0.983
Monthly mortgage payments*	10.231	23.786	19.046	32.868
Northwest	0.116	0.320	0.097	0.297
Northeast	0.172	0.377	0.207	0.405
Centre	0.147	0.355	0.111	0.315
Madrid	0.102	0.303	0.118	0.323
East	0.206	0.405	0.274	0.447
South	0.201	0.401	0.160	0.367

*Thousand pesetas.

Table A2. Probit estimates for the probability of working

Variables	Coefficients	t-values
Constant	-4.716	-7.678
Annual net nonlabour income/1000000	-0.063	-2.570
Mortgage payments/10000	0.051	4.085
Age	0.220	7.011
$Age^2/100$	-0.289	-7.789
Secondary education	0.599	6.959
Higher education	1.298	14.386
Unemployment in last 5 years	-0.161	-2.336
Health	0.150	2.030
No. members >14	-0.072	-1.933
No. children < 14	-0.151	-3.070
Children/adult care	-0.180	-2.174
Northwest	-0.065	-0.376
Northeast	0.299	1.853
Centre	0.047	0.280
Madrid	0.240	1.384
East	0.499	3.166
South	0.068	0.423
Log L	-1090.59	
Sample size	2586	

Table A3. Wage equation [Dependent variable: log (gross wage)]

Variables	Coefficients	t-values
Constant	4.609	9.965
Age	0.081	4.260
$Age^2/100$	-0.085	-3.506
Secondary education	0.374	5.714
Higher education	0.749	7.766
Unemployment in last 5 years	-0.250	-5.602
Northwest	0.035	0.272
Northeast	0.071	0.583
Centre	0.121	0.955
Madrid	0.143	1.142
East	0.072	0.582
South	0.052	0.424
λ	-0.030	-0.281
R^2	0.4897	
Adjusted R^2	0.4788	
Sample size	576	

[1] See Blundell and MaCurdy (1999) for a complete and recent discussion on those issues related to estimating labour supply models.

[2] See the seminal papers by Heckman (1974, 1979) for the first two issues and Blundell and Meghir (1986) for the third one.

[3] See, for example, Burtless and Hausman (1978) and García (1991a), among others.

[4] See Blundell *et al*. (1987).

[5] See, for example, Van Soest *et al*. (1990), Dickens and Lundberg (1993) and Bloemen (2000).

[6] See Hausman and Ruud (1984), Bourguignon and Chiappori (1992) or Fortin and Lacroix (1997).

[7] In Spain there are several empirical studies of female labour supply, some of them taking into account the characteristics of the budget set [García *et al*. (1989, 1993), Segura (1996), Álvarez and Prieto (2000) and Arrazola *et al*. (2000)], whereas this is not the case in other papers [Martínez-Granado (1994), Alonso and Fernández (1995), García and Molina (1998), Fernández *et al*. (1999) or Fernández (2000)].

[8] García *et al*. (1989, 1993) and Segura (1996) simplify the budget set assuming that there are only three tax brackets, whereas Álvarez and Prieto (2000) and Arrazola *et al*. (2000) do not specify the entire budget restriction.

[9] See García *et al*. (1989) for an empirical analysis of 1988 reform of the system of direct taxation in Spain moving from joint to either joint or separate taxation.

[10] The Hausman method (Hausman, 1981) has been often used in the empirical studies about labour supply with taxes. See, for example, Zabalza (1983), Arrufat and Zabalza (1986), Bourguignon and Magnac (1990) or Colombino and del Boca (1990). Another possibility is the use of the instrumental variables method. Blomquist (1996) and Blundell and MaCurdy (1999) compare both techniques.

[11] In particular the functional form of the utility function is:

$$U = \left(\frac{1}{a_2}\right)\left(h - \frac{a_1}{a_2}\right) exp\left(\frac{a_2 c - h + \mathbf{bX} + e}{h - \frac{a_1}{a_2}}\right)$$

This functional form has been often used in the literature about labour supply. See, for example, Hausman (1981), Colombino and del Boca (1990), Triest (1990) or Van Soest *et al*. (1990) .

[12] See Suárez (2000) for an empirical analysis of female labour supply in Spain when there are job offer restrictions.

[13] This is a way of avoiding the nonconvexity which would be generated by considering both regimes simultaneously.

[14] See García (1991b) for a complete discussion on the implications of the way of carrying out this kind of instrumental approach when estimating labour supply models.

[15] The evidence in the literature about the values of the standard deviations is varied. For example, in Arrufat and Zabalza (1986) and in García *et al*. (1993) for the Spanish case, the standard deviation of the preference error is greater than the other, whereas Triest (1990) finds the contrary in some of his estimates.

[16] For the Spanish case, Segura (1996) computes income elasticities of hours conditional on participation that are negative and smaller than one.