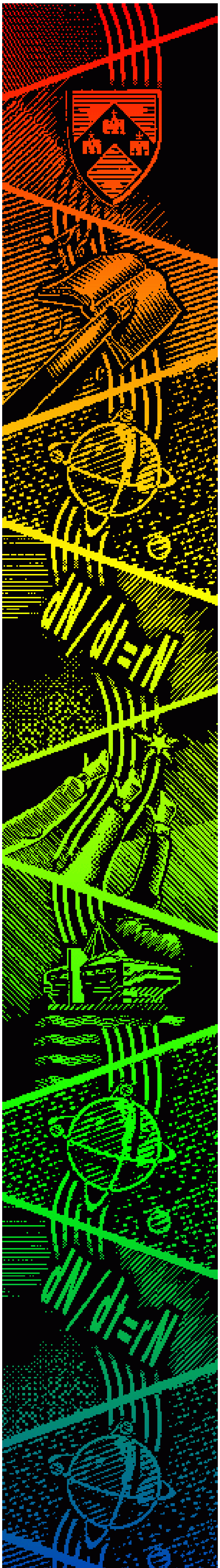

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Estimation of Alternative Models of Female Labour Supply with Fixed Travel Costs

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Abstract

We formalise the joint choice of labour force participation and mode of travel to work together with the hours of work decision for unitary and collective households. Conditioning on the primary workers decisions, we analyse the decisions of the secondary worker in a simplified setting in which the amount of work travel is independent of hours of work. On a matched sample from the BHPS and the NTS we find that car ownership is important in modal choice but the correlation between modal choice and the participation decision is negligible. We find that households behave somewhere between unitary and collective households in partially pooling groups of individual expenditure or income items.

1 Introduction

There is an extensive literature on labour supply and participation decisions at the individual level, some of which recognises the nonconvexities that arise in an individuals choice problem from fixed cost elements such as the costs of training, travel to work or equipment or more usually from benefit programs where the criteria for eligibility of benefit depend on labour income. In fact the literature on fixed costs of work is quite small but finds that such costs are important; we do not know of any other study of the effects of work travel costs on hours worked and participation.

There is a smaller literature which puts the labour supply decision in a multi-individual household context (Fortin & Lacroix, 1997, Blundell & Chiappori, Chiuri, 1997). In this paper we wish to examine the labour supply decisions of individuals who cohabit and who face fixed costs of travel to work. To do this we apply the household utility approach and the collective approach based on Pareto efficient decision making.

We develop a theory model which includes the money and time costs of travel to work by either car or public transport and which can be applied to households with a unitary household utility function and to households which act as a collective in the Chiappori sense. The transport technology includes both fixed and variable elements with the latter varying with the number of work trips and/or hours of work. With only fixed travel costs the optimal modal choice is independent of preferences or hours worked and is purely a matter of efficiency: minimise the monetary equivalent of the combination of time and money costs of travel. This fails to be true with variable costs since then the net wage varies with the quantity and mode of travel and through this with the hours worked.

In total the households we model have a complicated menu of choices: each adult in the household has to decide whether or not to work; how to travel to work and how many hours to work. We focus on just some of these choices taking households with exactly two adults of which the male always works. We take the male's participation decision, travel mode and hous of work as exogenous and examine the secondary workers decisions conditional on these. There is a variety of decision rules that the household could use to determine travel, consumption and work/leisure decisions. We model the secondary workers decisions in a way which allows us to at least partially test between a unitary and a collective model of how the household works.

We find that decisions of the secondary worker about participation and modal choice are mutually independent. That there are effects of travel costs on the participation decison and that generally travel by car will be preferred when a car is available. We also find that the household seems to be acting not like a unitary utility maximiser but also not like a collective. It is as if groups of exogenous income or costs are pooled but different types of income or cost are not pooled together.

2 The Model

We model a two adult household which possesses at least one car, and assume that each household member has an individual utility function deriving utility from private individual consumption of a single synthetic consumption good and from leisure. The household has some non labour income which accrues to the household as a whole. If any household member works then there is a variable cost of travel to work; travel can be by public transport in which case the variable cost is the fare; or it can be by car in which case the variable cost is the running cost of the car. The household also incurs a user cost C of owning the car as a whole which consists of annual taxes, insurance, depreciation, etc. The basic unit of travel we work with is the idea of a work trip-a one-way journey to or from work. Thus the household budget constraint has the form:

$$\sum q_i x_i + \sum p_i^j n_i^j = Y + \sum w_i H_i - C \tag{1}$$

where Y is the aggregate household non labour income - in fact subsequently in the collective model we can break this down into two components Y_1 and Y_2 for the two household adults. w_i is the wage rate and H_i the hours of work of individual i; q_i is the price per unit of consumption and x_i the quantity consumed of the private consumption good of individual i. $p_i^j n_i^j$ is the monetary cost of the number of work travel trips n_i associated with the j^{th} transport mode used by individual i and is equal to $p_i^c n_i^c$ if the car is mainly used and to $p_i^p n_i^p$ if public transport is mainly used. So for example p_i^c is the cost of each car work trip by individual i. Each individual also has a time endowment which can be used for work, leisure or travel: $T_i = L_i + H_i + t_i^j n_i^j$ where t_i^j can either be t_i^c or t_i^p depending on which method is mainly used and measures the travel time of a work trip for a particular mode and individual. Finally, the total amount of travel to work has both a fixed and a variable component, which we model by $n_i^j = a_i + b_i H_i$. If $a_i = 0$ there is no fixed cost; the number of work trips in a time interval is proportional to hours worked. If $b_i = 0$ there is no variable cost; the number of work trips is independent of hours worked-eg if hours were fixed at say 35 per week for everyone then we would expect to observe 10 work trips per week for every worker.

3 Decision Rules For The Household

3.1 Participation and Travel Mode Choices

In our empirical application we take a sample of two adult households in which the first household member always chooses to work and selects a particular main means of travel to work. We do not attempt to explain these choices here but treat them as exogenous; it is substantiated by the sample information (see below). But we do model the participation and mode of travel choice of secondary workers in the household. We do this by using an index function approach: let H^* be a latent variable describing the propensity of the secondary worker to work; we model the work decision by assuming that the secondary worker chooses to work if $H^* = Z_h\gamma + u_h > 0$; and if this holds then we assume that there is a second index variable C^* representing the propensity to travel to work mainly by car such that if $C^* = Z_c\delta + u_c > 0$ the secondary worker mainly travels to work by car. Of course we could interpret this modelling as coming from a discrete choice framework. We take these decisions to be made independently of the decision on how many hours to work given that the secondary worker has chosen to work and chosen a mode of travel to work. There are several reasons for this: one is simplicity; but also there is evidence from earlier literature and from introspection that decisions on whether to work at all and how to travel to work are made on the basis of factors such as the availability of a car for work travel; on the demographic circumstances at home, the local unemployment rate as well as on variables that might affect the hours of work such as the wage rate.

3.2 Household Utility Model

With a monolithic household utility approach and using the transport technology and cost equations, the household choice problem is

$$\max U(x_1, x_2, L_1, L_2) \tag{2}$$

subject to

$$\sum q_i x_i + \overline{w}_1^j L_1 + \overline{w}_2^z L_2 = Y^{jz} + \overline{w}_1^j T_1 + \overline{w}_2^z T_2 \tag{3}$$

with individual $i = 1$ choosing mode j and individual $i = 2$ choosing mode z, and

$$Y^{jz} = Y - C - \pi_1^j - \pi_2^z \tag{4}$$

$$\pi_{1(2)}^{j(z)} = a_{1(2)} \left(p_{1(2)}^{j(z)} + w_{1(2)} t_{1(2)}^{j(z)} \right) / \left(1 + b_{1(2)} t_{1(2)}^{j(z)} \right) \tag{5}$$

$$\overline{w}_{1(2)}^{j(z)} = \left(w_{1(2)} - b_{1(2)} p_{1(2)}^{j(z)} \right) / \left(1 + b_{1(2)} t_{1(2)}^{j(z)} \right) \tag{6}$$

$\pi_{1(2)}^{j(z)}$ reflects the fixed part of the money and time costs of travel for a particular individual with a particular mode. $\overline{w}_{1(2)}^{j(z)}$ reflects the reduction in the net wage of a worker caused by the variable part of the time and money cost. When travel trips are independent of hours worked (travel is just a fixed cost and $b_i = 0$) the household budget constraint becomes:

$$\sum q_i x_i + \sum_{l=j,z} (p_i^l + w_i t_i^l) a_i + \sum w_i L_i = Y + \sum w_i T_i - C \tag{3.2'}$$

In this case with travel trips fixed independently of hours of work the choice problem for a two worker household is:

$$\max U(x_1, x_2, L_1, L_2) \tag{3.1}$$

subject to

$$\sum q_i x_i + \sum_{l=j,z} (p_i^l + w_i t_i^l) a_i + \sum w_i L_i = Y + \sum w_i T_i - C \tag{3.2'}$$

Notice that in this case the choice of travel mode is purely one of selecting the lowest time+money method ie for individual i that which minimises $(p_i^l + w_i t_i^l)a_i$. The decision to work or not has a nonconvexity in the budget constraint, but for someone who has decided to work the hours of work are affected by travel costs only as an income effect.

If there is actually a single public consumption good this specialises further to

$$\max U(x, L_1, L_2) \tag{3.1'}$$

subject to

$$qx + \sum_{l=j,z} (p_i^l + w_i t_i^l)a_i + \sum w_i L_i = Y + \sum w_i T_i - C \tag{3.2'}$$

which we can rewrite as

$$qx + \sum w_i L_i = Y^* \tag{3.2''}$$

A special functional form for the household problem is the LES:

$$U(x, L_1, L_2) = \alpha \ln(x - \overline{x}) + \beta_1 \ln(L_1 - \overline{L}_1) + \beta_2 \ln(L_2 - \overline{L}_2) \tag{7}$$

with $\alpha > 0, \beta_i > 0, \alpha + \sum \beta_i = 1$. The solution to this problem is:

$$x = \overline{x} + \alpha \left(Y^* - q\overline{x} - w_1\overline{L}_1 - w_2\overline{L}_2\right)/q \tag{8}$$

$$L_1 = \overline{L}_1 + \beta_1 \left(Y^* - q\overline{x} - w_1\overline{L}_1 - w_2\overline{L}_2\right)/w_1 \tag{9}$$

$$L_2 = \overline{L}_2 + \beta_2 \left(Y^* - q\overline{x} - w_1\overline{L}_1 - w_2\overline{L}_2\right)/w_2 \tag{10}$$

Given that the solution above is conditional on the mode combination jz, the labour supplies of individual i, assuming that he/she works, is then given by:

$$H_i^{jz} = (T_i - L_i - t_i^l a_i)/(1 + t_i^l b_i); \;\; i = 1, 2; \; l = j, z \tag{11}$$

which in the case of a fixed number of work trips ($b_i = 0$) becomes

$$H_1^{jz} = T_1 - t_1^j a_1 - \overline{L}_1 - \beta_1(Y^* - q\overline{x} - w_1\overline{L}_1 - w_2\overline{L}_2)/w_1 \quad (12)$$

$$H_2^{jz} = T_2 - t_2^z a_2 - \overline{L}_2 - \beta_2(Y^* - q\overline{x} - w_1\overline{L}_1 - w_2\overline{L}_2)/w_2 \quad (13)$$

Work travel of this form has two influences on hours worked: first the fixed cost serves to reduce disposable nonlabour income thus tending to increase hours worked; second it reduces the effective time endowment thus reducing time available for leisure which will tend to reduce hours worked.

3.3 An Individual Utility Model: The Collective Approach

As an alternative to the household utility model, we focus on the Chiappori framework, according to which the household could agree on a distribution of welfare between the two household members and ensure that decisions are taken in a Pareto efficient way given this desired distribution. There is no household utility function as such but each household member has his/her own utility function; consumption is also private rather than public; individual utility is given by $U_i(x_i, L_i)$ Given that individual utilities are separable we can analyse decentralisation of the aggregate problem into two individual problems:

$$\max U^i(x_i, L_i) \quad (14)$$

$$q_i x_i + w_i L_i = \phi_i + w_i T_i - (p_i^j + w_i t_i^j) a_i \quad (15)$$

where ϕ_i is the income sharing rule modelled as follows:

$$\phi_1 = d_o + d_1 w_1 T_1 + d_2 w_2 T_2 + d_3 Y_1 + d_4 Y_2 + d_5 p_1^j a_1 + d_6 w_1 t_1^j a_1 + d_7 p_2^j a_2 + d_8 w_2 t_2^j a_2 \quad (16)$$

and $\phi_2 = Y - \phi_1$[1]. We can either think of (16) as an empirical rule reflecting the outcome of whatever intra-household bargaining process is going on; or we could

[1] Car user cost has been neglected.

think of restricting its form to be consistent with some specific household decision process. A prime example would be that in which there is an individualistic household welfare function depending only on the individual utility functions. This special case of the household utility approach then imposes restrictions particulary of income pooling on the sharing rule (see below).

After introducing the LES functional form for individual utility, the male problem is:

$$\max U(x_1, L_1) = \delta_1 \ln(x_1 - \overline{x}_1) + \gamma_1 \ln(L_1 - \overline{L}_1);\ \delta_1 + \gamma_1 = 1 \tag{17}$$

subject to

$$q_1 x_1 + w_1 L_1 = \phi_1 + w_1 T_1 - (p_1^j + w_1 t_1^j) a_1$$

while the female problem can be represented as:

$$\max U(x_2, L_2) = \delta_2 \ln(x_2 - \overline{x}_2) + \gamma_2 \ln(L_2 - \overline{L}_2);\ \delta_2 + \gamma_2 = 1 \tag{18}$$

subject to

$$q_2 x_2 + w_2 L_2 = \phi_2 + w_2 T_2 - (p_2^j + w_2 t_2^j) a_2$$

The solution to individual 2's problem is:

$$x_2 = \overline{x}_2 + \delta_2 \left[Y - \phi_1 + w_2 T_2 - w_2 \overline{L}_2 - q_2 \overline{x}_2 - (p_2^j + w_2 t_2^j) a_2 \right] / q_2 \tag{19}$$

$$L_2 = \bar{L}_2 + \gamma_2 \left[Y - \phi_1 - w_2 T_2 - w_2 \overline{L}_2 - q \overline{x}_2 - (p_2^j + w_2 t_2^j) a_2 \right] / w_2 \tag{20}$$

Hence labour supply conditional on the mode combination jz is given by:

$$H_2^{jz} = T_2 - t_2^z a_2 - \overline{L}_2 - \gamma_2 \frac{\left[Y - \phi_1 + w_2 T_2 - w_2 \overline{L}_2 - q \overline{x}_2 - (p_2^z + w_2 t_2^z) a_2 \right]}{w_2} \tag{21}$$

After substituting for the income sharing rule specification, H_2^{jz} becomes:

$$\begin{aligned} Hjz_2 \quad = \quad & [1 - \gamma_2 (1 - d_2)] T_2 + (1 - \gamma_2) \overline{L}_2 - t_2^z a_2 - \gamma_2 \frac{(1 - d_3) Y_1 - (1 - d_4) Y_2}{w_2} + \\ & -\gamma_2 \frac{-d_o - d_1 T_1 - q \overline{x}_2 - d_5 p_1^j a_1 - d_6 w_1 t_1^j a_1 - (1 + d_7) p_2^z a_2 - (1 + d_8) w_2 t_2^z a_2}{w_2} \end{aligned} \tag{22}$$

where $Y_1 + Y_2$ was substituted for Y.

3.4 The Unrestricted Model

We can think of testing between the unitary and collective approaches by introducing an unrestricted labour supply equation for the secondary worker (Fortin-LaCroix):

$$\begin{aligned} H_2 &= b_1 T_2 + b_2 \overline{Z}_2 + b_3 T_1 \frac{w_1}{w_2} + b_4 \overline{Z}_1 \frac{w_1}{w_2} + b_5 \frac{Y_1}{w_2} + b_6 \frac{Y_2}{w_2} + \\ &\quad + b_7 a_1 \frac{p_1^j}{w_2} + b_8 a_1 \frac{t_1^j w_1}{w_2} + b_9 a_2 \frac{p_2^j}{w_2} + b_{10} t_2^j a_2 + b_{11} \frac{q_1}{w_2} + b_{12} \frac{q_2}{w_2} \end{aligned} \tag{23}$$

derived from the hypothesis that the secondary worker's demand for leisure is linear in the budget share, and homogeneous of degree zero in all prices and incomes $\left(q_1, q_2, p_1^j, w_1, w_2, Y_1, Y_2\right)$. $\overline{Z}_1$ and $\overline{Z}_2$ are vectors of both individual and household characteristics.

In order to develop the sets of parametric restrictions imposed by the unitary and the collective frameworks and test each of them against the more general unrestricted model as Fortin and Lacroix (1997) do, we would need to estimate a system of household members' labour supply equations.

More precisely, given the male and the female labour supply H_1 and H_2, we would be able to derive two restrictions which must hold within the unitary framework:

1. the income pooling hypothesis, according to which it is only the level of total household disposable resources rather than its distribution among family members that is relevant for the determination of individual labour supplies. These resources consist of nonlabour income net of work travel

costs

$$Y_1 + Y_2 - \sum_{l=j,z} (p_i^l + w_i t_i^l) a_i + \sum w_i T_i \tag{24}$$

thus implying that:

$$\delta H_1/\delta Y_1 = \delta H_1/\delta Y_2 = -\delta H_1/\delta(p_1^j + w_1 t_1^j)a_1 = -\delta H_1/\delta(p_2^z + w_2 t_2^z)a_2 \tag{25}$$

and

$$\delta H_2/\delta Y_1 = \delta H_2/\delta Y_2 = -\delta H_2/\delta(p_1^j + w_1 t_1^j)a_1 = -\delta H_2/\delta(p_2^z + w_2 t_2^z)a_2 \tag{26}$$

In fact it is possible to test also for partial income pooling in which only some of the equalities in (25)-(26) hold.

2. the usual Slutsky restrictions, provided that the household behaves as predicted by the standard theory of individual consumer, and assuming an interior solution for both $H_1$and H_2. In particular, if $S_{ij} = \delta H_i/\delta w_j - H_j \delta H_i/\delta Y$, where $i, j = 1, 2$, is the compensated own/cross wage effect, symmetry of compensated cross wage effects requires that $S_{12} = S_{21}$, non-negativity of compensated own wage effects requires $S_{ii} \geq 0$, while non-negativity of the determinant of the Slutsky matrix implies that $S_{11}S_{22} - S_{12}^2 \geq 0$.

On the other hand, the collective setting $H_i = \widetilde{H}_i [w_i, \phi(w_1, w_2, Y_1, Y_2)]$ may be thought as the outcome of each individual utility maximisation process conditional on his/her budget constraint, which arises from the income allocated to him/her through the sharing rule $\phi(w_1, w_2, Y_1, Y_2)$. This then imposes the Slutsky restriction on the compensated individual labour supply, such that: $\delta\widetilde{H}_i/\delta w_i - H_i \delta\widetilde{H}_i/\delta\phi_i \geq 0$, where $i = 1, 2$; $\phi_1 = \phi(w_1, w_2, Y_1, Y_2)$ and $\phi_2 =$

$y - \phi(w_1, w_2, Y_1, Y_2)$. If this restriction is satisfied, then the parameters of the sharing rule ϕ can be uniquely recovered up to an additive constant.

Since here we only estimate the secondary worker labour supply, the only restrictions that can be tested for the unitary model are forms of the income pooling hypothesis and the non-negativity of compensated own wage effect.

Recall that the female labour supply equation is given by (13) according to the unitary model, and by (22) in the collective model.

Therefore, in the LES setting, the parameter restrictions that can be tested are:

(a) $b_5 = b_6$ and $b_7 = b_8 = b_9 = b_{10} = -b_5$;

(b) $b_i = 0$ for $b_i = 3, 4$.

Moreover, if we assume that only $x = x_1 + x_2$ enters the household utility function, then an additional parameter restriction is:

$b_{11} = b_{12}$.

If these restrictions do not hold, then we could reject the unitary model; however, the converse might not be true (in other words, the household specification might still be rejected in spite of accepting the income pooling hypothesis).

On the other hand, the restriction $S_{22} \geq 0$ can be tested for the collective model. By resorting to the Slutsky equation, we can use (23) to define:

$$S_{22} = \frac{\delta H_2}{\delta w_2} - \frac{\delta H_2}{\delta Y} H_2 = -\frac{H_2}{w_2}(b_5 - 1) + \frac{1}{w_2}\left(b_1 T_2 + b_2 \overline{Z}_2\right) \qquad (27)$$

and impose the condition:

(c) $b_5 < 1$ and $b_i > 0$ with $i = 1, 2$.

The following table shows a comparison among the parameters of the unitary, the collective and the unrestricted model:

Table 1
Comparison among parameters

Unrestricted	Unitary	Collective
b_1	$(1-\beta_2)$	$[1-\gamma_2(1-d_2)]$
b_2	$(1-\beta_2)\overline{L}_2$	$(1-\gamma_2)\overline{L}_2$
b_3	$-\beta_2$	$\gamma_2 d_1$
b_4	$-\beta_2\overline{L}_1$	0
b_5	$-\beta_2$	$1-d_3$
b_6	$-\beta_2$	$-\gamma_2(1-d_4)$
b_7	$+\beta_2$	$+\gamma_2 d_5$
b_8	$+\beta_2$	$+\gamma_2 d_6$
b_9	$+\beta_2$	$+\gamma_2(1-d_7)$
b_{10}	$-(1-\beta_2)$	$-[1-\gamma_2(1-d_8)]$
b_{11}	$-\beta_2\overline{x}_1$	0
b_{12}	$-\beta_2\overline{x}_2$	$\gamma_2\overline{x}_2$

4 The Stochastic Specification

The sample of households taken in our empirical application is generated by individuals (namely, the secondary workers) making two choices: whether to work or not and, in the first case, whether to travel to work by car or by public transport. In other words, the individuals in the sample decide to belong to one group or another. In order to deal with the selectivity bias issue, we need to acknowledge that the observed distribution of hours of work, truncated at the zero level, was determined by these choices. An appropriate procedure yielding consistent estimates of a truncated regression is the Heckman two-stage model, which corrects for the selectivity bias by conditioning on a previous estimation of the reduced form of the criterion function leading to selectivity.

Let us define the labour supply functions for the secondary workers who use car and for the secondary workers who use public as:

$$H_c = X_c\beta + \epsilon_c \tag{28}$$

$$H_p = X_p \beta + \varepsilon_p \tag{29}$$

where the regressors X_c and X_p differ only in the money and time costs of work travel, and let us recall the index variables:

$$H^* = Z_h \gamma + u_h \tag{30}$$

$$C^* = Z_c \delta + u_c \tag{31}$$

The vector of random errors $[u_h, u_c, \epsilon_c, \epsilon_p]$ is distributed as a multivariate normal $N_4\left(0, \sum\right)$ and

$$\sum = \begin{bmatrix} 1 & \rho & \sigma_{u_h,\varepsilon_c} & \sigma_{u_h,\varepsilon_p} \\ \rho & 1 & \sigma_{u_c,\varepsilon_c} & \sigma_{u_c,\varepsilon_p} \\ \sigma_{u_h,\varepsilon_c} & \sigma_{u_c,\varepsilon_c} & \sigma^2_{\varepsilon_c} & \sigma_{\varepsilon_p,\varepsilon_c} \\ \sigma_{u_h,\varepsilon_p} & \sigma_{u_c,\varepsilon_p} & \sigma_{\varepsilon_p,\varepsilon_c} & \sigma^2_{\varepsilon_p} \end{bmatrix}$$

where $1, 1$, $\sigma^2_{\varepsilon_c}$, $\sigma^2_{\varepsilon_p}$ are the variances of $u_h, u_c, \epsilon_c, \epsilon_p$ respectively; the terms $\sigma_{u_j,\varepsilon_i}$ (with $j = h, c$ and $i = c, p$) account for the interdependence between the error term in each of the selectivity criterion and in each of the labour supply equations; ρ is the correlation between the selectivity criteria error terms u_h and u_c. X_j includes household and individual non labour incomes, wage rates, individual full incomes, travel costs and travel times as well as demographic variables. Z_h and Z_c stand for different sets of variables, the former including demographic characteristics of household, female and household non labour income, locational variables and the local unemployment rate, the latter encompassing variables such as secondary worker's access to car usage as well as proxies for public transport availability.

If $H^* > 0$, the individual decides to join the labour force. If $C^* > 0$, the individual chooses to use car for her travel trips. Therefore, H_c is observed only if $H^* > 0$ and $C^* > 0$; conversely, H_p is observed only if $H^* > 0$ and $C^* < 0$, while the set $H^* < 0$ and $C^* > 0$ is empty. Note moreover that C^* is observed only on the subsample of observations for which $H^* > 0$, that is the mode choice arises only for those who decided to work.

In the following, the estimation of labour supply and modal choice will be performed through a two-step procedure. First, the selection rule accounted for by $H^*$and C^* is estimated as a reduced form bivariate probit model with sample selection. In particular, the log-likelihood function which accounts for the set of probabilities: $\Pr(H^* > 0 \bigcap C^* > 0)$; $\Pr(H^* > 0 \bigcap C^* < 0)$; $Pr(H^* < 0)$ - where the three terms refer respectively to car travelling workers, public transport travelling workers and non workers - is

$$\sum_{H^*>0,C^*>0} \ln \Phi_2 \left[Z_h\gamma, Z_c\delta, \rho\right] + \sum_{H^*>0,C^*<0} \ln \Phi_2 \left[Z_h\gamma, -Z_c\delta, -\rho\right] + \sum_{H^*<0} \ln \Phi \left[-Z_h\gamma\right] \tag{32}$$

This stage provides the estimates of the parameters (γ, δ, ρ) which are used to generate the selection correction terms, entered as auxiliary regressors in the hours equation, defined as follows[2]:

$$E\left(\varepsilon_c | H^* > 0 \bigcap C^* > 0\right) = \sigma_{\varepsilon_c}\sigma_{\varepsilon_c uh} * \lambda_{h1} + \sigma_{\varepsilon c}\sigma_{\varepsilon_c u_c} * \lambda_{c1} \tag{33}$$

where the 'λ' variables in the regression are respectively:

$$\lambda_{h1} = \frac{\phi\left(-Z_h\gamma\right)\Phi\left[\left(Z_c\delta - \rho Z_h\gamma\right)/\sqrt{(1-\rho^2)}\right]}{\Phi_2\left(Z_c\delta, Z_h\gamma, \rho\right)} \tag{34}$$

$$\lambda_{c1} = \frac{\phi\left(-Z_c\delta\right)\Phi\left[\left(Z_h\gamma - \rho Z_c\delta\right)/\sqrt{(1-\rho^2)}\right]}{\Phi_2\left(Z_c\delta, Z_h\gamma, \rho\right)} \tag{35}$$

and

$$E\left(\varepsilon_p | H^* > 0 \bigcap C^* < 0\right) = \sigma_{\varepsilon_p}\sigma_{\varepsilon_p u_h} * \lambda_{h2} + \sigma_{\varepsilon_p}\sigma_{\varepsilon_p u_c} * \lambda_{c2} \tag{36}$$

where the 'λ' variables in the regression are now

[2] Φ_2 is the bivariate normal CDF, while Φ and ϕ are, respectively, the univariate normal CDF and PDF.

$$\lambda_{h2} = \frac{\phi\left(-Z_h\gamma\right)\Phi\left[-\left(Z_c\delta - \rho Z_h\gamma\right)/\sqrt{(1-\rho^2)}\right]}{\Phi_2\left(Z_h\gamma, -Z_c\delta, -\rho\right)} \tag{37}$$

and

$$\lambda_{c2} = \frac{\phi\left(-Z_c\gamma\right)\Phi\left[-\left(Z_h\delta - \rho Z_c\gamma\right)/\sqrt{(1-\rho^2)}\right]}{\Phi_2\left(Z_h\gamma, -Z_c\delta, -\rho\right)} \tag{38}$$

Notice that if $\rho = 0$, (32) specialises to

$$\sum_{H^*>0} \ln\phi(Z_h\gamma) + \sum_{C^*>0} \ln\phi(Z_c\delta) + \sum_{C^*<0} \ln\phi(-Z_c\delta) + \sum_{H^*<0} \ln\Phi\left[-Z_h\gamma\right] \tag{39}$$

so that the modal choice can be estimated from a univariate probit on only the sample of workers and the participation decision by a univariate probit on the full sample.

A further issue that needs to be paid attention is the endogeneity of the wage rate with respect to hours of work. This is a well known result of the calculation of the wage rate by dividing total net of tax labour income earned in a given period by total hours of work recorded in the period itself, as well as arising from unobservable components that might influence both wage rates and hours. This issue has been solved by instrumenting both male and female wage rates with exogenous socio-demographics and regional variables, including individual characteristics, such as the age, the school leaving age, the work experience and qualifications, as well as regional variables and demand side variables (namely, the unemployment rate [3]); the women wage equation includes also the household non labour income and the husband's wage rate. Moreover, following the Heckman two-step procedure, the female wage equation has been corrected for selectivity by adding as an extra regressor the inverse of the Mill's ratio

[3] Source: Employment Gazette - Department of Employment, London H.M.S.O. 1991.

derived from a reduced univariate probit for women' labour participation decision; while the male wage equation has been run as a truncated model. These estimations provided predictions that replaced the endogenous variables in the female labour supply and that allowed the estimation of a bivariate structural model for labour participation decision and travel choice. Results are presented in the Appendix.

5 The Data

We use data from the second wave , 1992, of the British Household Panel Study (BHPS) which covers 5227 eligible households and 9845 individuals; respondents were interviewed at a date between September 1992 and April 1993. Our sample is of 839 households, of which 524 have both male and female in employment at the date of interview. This subsample was extracted by including only married couples, having at least the husband employed and whose working members used either car or public transport for their work trips.

Descriptive statistics of the main household characteristics are summarised in the following table, while table 3 lists mean and standard deviation of the economic, demographics and travel variables for men and women for the subsample of working women:

Table 2
Sample statistics - whole sample

Variables	Min	Max	Mean	Std. Dev.
No of persons in the household	2	8	3.32	1.13
No in employment in the household	1	5	1.82	0.73
No in household of working age	1	6	2.26	0.72
No children	0	5	0.99	1.07
0-2 years	0	2	0.14	0.37
3-4 years	0	2	0.14	0.36
5-11 years	0	4	0.40	0.72
12-15 years	0	3	0.25	0.52
16-18 years	0	1	0.35E-02	0.6E-01
House type: detached	0	1	0.31	0.46
semi-detached	0	1	0.41	0.49
terraced	0	1	0.21	0.41
flat	0	1	0.07	0.24
House tenure: owned	0	1	0.88	0.32
with mortgage	0	1	0.79	0.41
No of cars	0	3	1.60	1.17
Annual household non-labour income	0	26533.01	1941.37	2450.52

Table 3
Sample statistics - working women sample

Variable	Men	Women
Age	42.05 (10.43)	40.14 (10.46)
Weekly hours of work: normal	39.13 (9.14)	27.45 (11.14)
overtime	6.10 (7.56)	2.65 (5.31)
Hourly wage	6.25 (3.70)	4.81 (2.02)
Monthly take-home pay at last payment	956.28 (1441.57)	490.80 (434.93)
Last month non-labour income	46.92 (100.92)	67.57 (71.83)
Daily minutes spent travelling to work: by car	26.24 (24.10)	18.22 (13.34)
by public	57.15 (33.03)	40.72 (25.05)
Car usage	0.87 (0.38)	0.79 (0.41)
Public transport usage	0.13 (0.33)	0.21 (0.41)

Note: In the table, mean (standard deviation)

The distribution of men's hours has a peak between 35 and 40 hours a week (fig. 1), while women's hours distribution has a peak at 40-45 and two minor peaks at 20-25 and 30-35 (fig. 2).

The percentage of women in employment amounts to 62.5 percent. The following tables show crosstabulations of female labour force participation by the number of persons in the household, the number of children, and the number of children disaggregated into age groups:

Table 4
Labour force participation by persons in household

Participation	Number of persons 2	3	4	5+	Total
No	84	75	109	47	315
Yes	179	113	167	65	524
Total	263	188	276	112	839

Table 5
Labour force participation by number of children

Participation	Number of children 0	1	2	3	4 +	Total
No	129	61	92	28	5	315
Yes	252	107	128	32	5	524
Total	381	168	220	60	10	839

Table 6
Labour force participation
by number of children of distinct age groups

	0-2 years			3-4 years			5-11 years			12-15 years		
Part.	0	1	2	0	1	2	0	1	2+	0	1	2+
No	249	60	6	244	67	4	222	63	30	275	33	7
Yes	481	41	2	478	46	-	379	87	58	391	106	27
Total	730	101	8	722	113	4	601	150	88	666	139	34

Table 4 shows that the percentage of women who choose to participate decreases with the household size; in particular, labour force participation declines as the number of children rises passing from 66 percent when the household is childless to 53 per cent when the number of children equals three (table 5). As expected, such a negative correlation is stronger when children are aged between zero and four years, while its sign is reversed when children between 12 and 15 years are present (table 6).

Labour force participation decision may be affected by car availability:

Table 7
Labour force participation by number of cars

	Number of cars				
Participation	0	1	2	3+	Total
No	14	197	90	14	315
Yes	19	190	272	43	524
Total	33	387	362	57	839

The participation rate increases as the number of cars in the household rises; however, such a pattern does not imply an unambiguous relationship of causality, since labour participation and car ownership decisions may be simultaneous.

Looking at modal choices for work trips, car usage seems to be affected primarily by car availability. As shown by table 3-8, 46 percent of the families in the sample own one car, while the percentage of two car households is slightly lower (43 percent):

Table 8
Car ownership

Number of cars	Number of households
0	33
1	387
2	362
3+	57
Total	839

As far as concerns the main method of transport used for work trips, about 90 per cent of male workers choose car, while about 21 per cent of women in employment use public transport.

The following table shows car usage by the secondary worker for work trips in one, two and 3+ car owner households respectively:

Table 9
Female car usage by car ownership

	Number of cars				
Car usage	0	1	2	3+	Total
No	19	79	15	2	110
Yes	-	111	257	41	414
Total	19	190	272	43	524

As expected, the proportion of secondary workers using car rises with car availability; this is confirmed by the following tables which crosstab car usage by male and female in 1, 2 and 3 or more cars households:

Table 10
Female and male car usage
by household car ownership

Car usage by:	1 car		2 cars		3+ cars	
	Male		Male		Male	
Female	No	Yes	No	Yes	No	Yes
No	14	67	1	14	-	2
Yes	41	70	17	240	3	38
Total	55	135	18	254	3	40

The BHPS does not report data on transport costs. To overcome this we combine the BHPS with the U.K. National Transport Survey (NTS) 1985-86, following the approach taken by Arellano & Meghir (1992)[4]in the study of female labour supply. The NTS contains detailed information on about 11,000 households; moreover, each family member interviewed recorded his/her journeys over a seven day period and reported travel purposes, modal choices as well as travelling times and costs. In order to combine the NTS and the BHPS data sets and to predict travel monetary costs for BHPS individuals, the following steps were followed.

First, an NTS subsample of married couples, with husband and wife both working and using either car or public transport methods for their work trips has been drawn.

Second, the compatibility of the two data sets was investigated using a set of overlapping variables, including both household characteristics (such as size and composition), individual characteristics (such as age, health status, part time versus full time job status, job type), house tenure variables, geographical

[4]The combination of two data sets is not new and many examples of estimates obtained by pooling cross-section and time series can be found in the literature (Maddala, 1971; Jorgenson, Lau and Stocker, 1982).

dummies (regions) and the travel time variable. A priori, there is no reason for BHPS and NTS to be incompatible: in fact, the variable definition is generally the same. This intuition was confirmed by the results of a t-test, which checked that the conditional means of the overlapping BHPS and NTS variables were not significantly different in the two data sets, (conditional on modal choice). More precisely, the statistic was obtained according to the following expression: $t = \frac{(\mu_x - \mu_y)/\sqrt{(N-1)s_x^2 + (M-1)s_y^2}}{\sqrt{NM(N-M-2)/(N+M)}}$ where N and M are the two sample sizes, $(\mu_x - \mu_y)$ the difference of the sample means, s_x^2 and s_y^2 the estimated variances.

After checking that the NTS and the BHPS samples may be thought as drawn from the same population, two OLS regressions were run - one for the NTS car users group and the other for the NTS public transport users group - having as dependent variables monetary travel costs and as independent regressors all the variables mentioned above[5]. These two regressions were then used to predict car and public transport costs for the BHPS observations.

6 The Empirical Results

6.1 The Bivariate Probit Model

Consider first the reduced bivariate probit estimates accounting for women's participation and car usage for work trips displayed in table 11[6].

[5] The R^2 was about 0.37 for the car travel costs regression and 0.31 for the public transport cost regression.

[6] The normality of the disturbance term is an essential requirement for the application of the probit model. Therefore, for each probit equation a likelihood ratio test has been carried out (the returned $\chi^2_{(2)}$ statistic is $\chi^2_{(2)} = 3.1693$ for the participation equation and $\chi^2_{(2)} =$ 0.2302 for the modal choice equation). Furthermore, each equation satisfies the hypothesis of homoscedastic disturbances ($\chi^2_{(3)} = 7.3108$ for the participation equation and $\chi^2_{(3)} = 5.4300$ for the modal choice equation). Finally, each equation has been tested for misspecification (Reset test: $\chi^2_{(5)} = 5.7701$ for the participation equation and $\chi^2_{(4)} = 1.4037$ for the modal choice equation). All the tests have been carried out as omitted variable tests (Orme, 1994).

Table 11
Bivariate Probit Estimates for car usage and labour force participation
Reduced form

Variables		Parameter estimate	Standard error	p
Participation equation				
constant		-3.0505	1.1648	***
household non labour income		-0.1790E-02	0.1434E-02	
female non labour income		-0.0142	0.2289E-02	***
number of children aged:	0 - 2 years	-0.3963	0.1539	***
	3 - 4 years	-0.6669	0.15835	***
	5 - 11 years	-0.0344	0.0862	
	12 - 15 years	0.3770	0.1263	***
couple no dependent children		0.4417	0.1547	***
detached and semi-detached house		-0.1533	0.1282	
mortgaged house		0.3659	0.1332	***
female age		0.1567	0.0506	***
female age squared		-0.2150E-02	0.6049E-03	***
female health status: good		0.5897	0.1990	***
female school leaving age		0.0290	0.0348	
husband's current job: civil servant		-1.0384	0.7277	*
access car usage by female		0.8034	0.1277	***
regional unemployment rate (%)		-0.0149	0.0386	
East Anglia		-0.3994	0.3186	
London		0.2678	0.2228	
North metropolitan		-0.3127	0.3303	
Wales		-0.4244	0.2547	**

Table 11
Bivariate Probit Estimates - continued -

Variables	Parameter estimate	Standard error	p
Car usage equation			
constant	-1.8801	0.8349	***
number of children	0.4366	0.2506	**
number of children aged 0 -2 years	-0.1256	0.4264	
no children per North non metropolitan	0.3225	0.7732	
no children per South East	-0.2943	0.3280	
no children per South West	-0.1758	0.9445	
no children per North West non met.	-0.4289	0.3357	
no children per East Midland	-0.1516	0.3774	
no children per West Midland met.	-0.1609	0.7755	
no children per North Western met.	-0.1950	0.4014	
no children per Scotland	0.0463	0.3788	
female health status: good	-0.4354	0.7214	
access car usage by female	2.1367	0.3220	***
no. of cars per employed in the household	1.5358	0.3844	***
house type: detached	0.1135	0.2490	
terraced	-0.0500	0.2727	
density (persons per hectare)	0.3600E-02	0.8458E-02	

Table 11
Bivariate Probit Estimates - continued -

Variables	Parameter estimate	Standard error	p
Car usage equation			
London	-1.2010	0.4298	***
North metropolitan	-0.8784	0.6388	*
North non metropolitan	0.5277	0.6705	
Scotland	-0.3975	0.4248	
Yorkshire and Humberside	0.0852	0.3089	
house owned	0.3504	0.2332	*
ρ	0.1477	0.3909	

Log L = -542.8548 n = 839 (for labour participation)
n = 513 (for car usage)

$***p \leq 0.01$ $** \ 0.01 < p \leq 0.05$ $* \ 0.05 < p \leq 0.10$

The participation equation includes:

- economic variables such as household and female non labour income;

- household composition variables, that is the number of children aged less than two, between three and four, between five and eleven, between twelve and fifteen, as well as household type variables (couple without dependent children);

- house type variables (detached and semidetached) and house tenure variables (mortgaged versus owned houses) as a proxy of the family wealth;

- individual characteristics, such as female age, health status, school leaving age and male employing organisation;

- access to car usage;

- demand side variables such as the regional unemployment rate and dummies for region of residence.[7]

As expected, the woman's participation decision is negatively affected by non labour income and by the presence of children aged less than four; on the other hand, the factors having a positive impact are the presence of children aged between twelve and fifteen, the absence of dependent children, the good health status and the fact of having a mortgage; finally, female age enters in a quadratic form. Among the regional variables, only the dummy corresponding to London is positive, probably denoting higher employment opportunities.

Car usage for work trips has been investigated conditional on female labour participation decision. Among the regressors - including family composition variables, interacted variables defined as the product of the number of children and the region of residence, house type and female health status -, the main factor affecting modal choice is car availability as is confirmed by the strong statistical significance of the dummy denoting access to a private vehicle and of the variable defining the number of cars per employed person in the household.

[7] Additional variables - such as geographical dummies - have been included both in the labour force participation and in the car usage equations. However, after carrying out a likelihood ratio test, they have been discarded having turned out to be insignificant.

Traffic congestion and public transport availability are captured through the dummies for house type, the density variable, as well as standard regions; among the latter, London is strongly significant and negative. Among the variables accounting for family wealth, house ownership has a positive sign as expected. Finally, car usage also seems positively related to the number of children: this probably accounts for the fact that car is used both to go to work and to accompany children to school.

Finally, ρ is positive, thus indicating that unobserved characteristics associated with higher employment rates are also associated with higher car usage rates for work trips, but highly insignificant. This implies that the participation decision and the modal choice are not simultaneous and that examining each decision separately would have been correct. This has implications also for the estimation of labour supply.

6.2 Estimation of Labour Supply Equation

The outcome of the bivariate probit estimation indicates that decisions on participation decision and modal choice are not simultaneous, that is the marginal distribution of ε_j $(j = c, p)$ is independent of u_c and follows the standard univariate distribution. So there is no need to estimate equations (3.23) and (3.24) separately, nor to use the selectivity correction terms given in (3.29) and (3.33).[8] Therefore, the continuous labour supply equation to be estimated is:

$$H = X\beta + \epsilon \tag{40}$$

[8] This was confirmed by the separate estimation of the labour supply equations (3.23) and (3.24), which was however carried out by using the selectivity correction terms reported in (3.29) - (3.33). As expected, in both cases only the term accounting for the correlation between labour force participation decision and labour supply was significant, while the term regarding the correlation between modal choice and labour supply was insignificant. In particular, λ_{h1} and λ_{h2}, appearing respectivily in equation (3.23) and (3.24), exhibited a t statistic equal to -2.204 and -1.855; on the other hand, λ_{c1} and λ_{c2} exhibited a t statistic equal to -0.501 and 0.033.

with X including car transport costs for the car user workers subsample and public transport costs otherwise. (3.34) defines labour supply conditional on the labour market entry decision; in order to correct for the selectivity bias this may generate, a standard Heckman model has been applied. In particular, the univariate probit accounting for labour force participation decision has been estimated, according to the specification of the discrete stage given in (3.25) (that is, the participation equation in table 3-11 run on its own; estimation results are shown in Appendix 3-1). Then, (3.24) has been estimated by OLS, according to the specification (3.21) of the unrestricted model, after having included the selectivity correction term derived from the probit model. As it is well known, the selectivity correction term, named also inverse Mill's ratio, is given by: $\lambda = \frac{\phi(Z_h\gamma)}{\Phi(Z_h\gamma)}$ (recall that the variance of u_h has been normalised to 1) and accounts for the conditional expected value: $E\left(\epsilon/u_h > -Z_h\gamma\right)$; the continuous labour supply equation estimated by OLS thus becomes:

$$H = X\beta + \varphi\lambda + v \tag{3.34'}$$

where φ is σ_{ε,u_h}, the correlation between ϵ and u_h. More on this estimation procedure, which treats the selectivity bias problem as an omitted variable problem, in Heckman (1979).

In both the unitary and the collective models the subsistence levels of leisure $\overline{L}_1$ and $\overline{L}_2$, have been defined as a function of demographic variables $\overline{Z}_1$ and $\overline{Z}_2$. These include individual characteristics such as health, age, employment status, qualifications, and on household variables such as the presence of children and of children below the age of two, the presence of people of employment age and the household size. Finally, all the variables accounting for $\overline{Z}_1$ have been interacted by the wage ratio w_1/w_2 according to the specification (3.21).

The following table reports the coefficients and the asymptotic standard errors[9] of the unrestricted labour supply equation [10]:

Table 12
Unrestricted model of labour supply

Parameters	Estimates	St. errors	p
$b_1 T_2$	35.0460	13.4530	***
b_2: female health status: good	-3.0150	2.6326	
female age	-0.0196	0.6040	
female employed in a firm	-1.0692	1.8579	
female qualification: university 1st degree	9.1260	4.4747	**
male age	0.0733	0.5767	
dummy for children	-28.6740	8.0309	***
dummy for children aged less than 2	14.2610	7.1066	**
number of people in employment age	8.1671	5.3276	*
household size	1.5943	4.2284	
$b_3 T_1$	8.5938	11.6260	
b_4: male health status: good*	-0.0808	2.1029	
male age*	0.0237	0.5015	
male employed in a firm*	0.0909	1.0728	
male qualification: university 1st degree*	-3.3023	5.0966	
female age*	-0.2249	0.5156	
dummy for children*	20.6590	7.0953	***
dummy for children aged less than 2*	-11.452	6.9453	**
number of people in employment age*	-3.6355	4.6482	
household size*	-3.5749	3.8277	

[9] The regressors of labour supply equation include estimated variables. In particular, recall that the observed wage, being endogenous, has been instrumented; transport costs have been predicted and the selectivity correction term has been constructed by using the univariate probit result for labour market participation decision (see Appendix 3-1 for further details). This in turn implies that standard errors should be corrected: nevertheless, in our case the correction could be exceedingly complicated by the high non linearity in some endogenous variable estimations and by the included correction terms. Results therefore need to be interpreted cautiously.

[10] The dependent variable has been defined as $H_2^* = H_2 + t^{c(p)} c_{02}$. The coefficient b_{5-6} concerns the variable accounting for household non-labour income which cannot be imputed to any household member; it is defined as the difference between the recorded household non labour income and the sum of the individuals non labour incomes.

Table 12
Unrestricted model of labour supply - continued -

Parameters	Estimates	St. errors	p
b_5	-0.1648	0.1141	*
b_6	0.1093	0.1692	
b_{5-6}	0.0426	0.1323	
b_7	-33.4340	19.3660	**
b_8	0.7403	0.4441	**
b_9	-8.4233	4.7282	**
b_{10}	5.4473	1.9389	***
b_{11}	32.1880	23.1630	*
λ	-6.5555	2.2538	***

n = 513
*Recall that these variables have been interacted with the ratio w_1/w_2
$R^2 = 0.2719$

Female labour supply is negatively influenced by the husband's non-labour income and monetary transport costs; male and female travel times have negative coefficients, with the latter being strongly significant.

Among the demographic variables, the number of children as well as the presence of children aged less than two are strongly significant; moreover, household composition variables as well as female qualification play a role in the determination of labour supply.

The significance of the term λ, accounting for the correlation between the continuous labour supply and the participation decision modelled through the univariate probit selection process, confirms that both the subsamples of working women using either car or public transport for work trips are not random.

Different restrictions have been imposed on the unrestricted model in order to test for the income pooling hypothesis; such restrictions and the corresponding F-statistics are reported in the following table:

Table 13
Income pooling restrictions

Restrictions		F statistic (p = 0.05)	Accept
$b_5 = b_6 = b_{5-6}$	(A)	F(2, 484) = 1.3963	Yes
$b_7 = b_9$	(B)	F(1, 484) = 1.5421	Yes
(A) and (B)	(C)	F(3, 484) = 1.4112	Yes
$b_8 = b_{10}$	(D)	F(1, 484) = 5.2747	No
(A) and (B) and $b_5 = b_7$	(E)	F(4, 484) = 2.4807	No
(D) and (E)	(F)	F(5, 484) = 3.0960	No
(F) and $b_5 = b_8$	(G)	F(6, 484) = 2.8451	No
$b_4 = 0$	(H)	F(10, 484) = 2.2548	No

Restrictions (A) through (G) test the household model, while restriction (H) concerns the pure collective one. To begin with, individuals' non-labour incomes, monetary and time transport costs have been collected into different groups and parameter restrictions have been imposed on each group separately - (A) through (D) -; then, in addition to the above ones, a single cross parameter restriction has been entered for non labour incomes and male and female transport costs (E); finally, equality among the coefficients of non labour income and of all the regressors mentioned so far have been imposed (G). In order to test for the collective model, the variables instrumenting for the subsistence level of the male leisure, $\overline{L}_1$, have been discarded. The test results would support the hypothesis of partial income pooling: in other words, recalling the income sharing rule in (3.14) $\phi_1 = d_o + d_1 w_1 T_1 + d_2 w_2 T_2 + d_3 Y_1 + d_4 Y_2 + d_5 p_1^j a_1 + d_6 w_1 t_1^j a_1 + d_7 p_2^j a_2 + d_8 w_2 t_2^j a_2$

it is as if $d_3 = d_4$, $d_5 = d_7$ but $d_6 \neq d_8$.

Parameter estimates of the restricted model are collected in table 14:

Table 14
The restricted model - Parameter estimates

Parameters	Estimates	St. errors	p
b_1T_2	35.2950	13.363	***
b_2: female health status: good	-3.1333	2.6296	
female age	-0.0565	0.6043	
female employed in a firm	-1.1803	1.8567	
female qualification: university 1st degree	9.8267	4.4642	**
male age	0.0651	0.5770	
dummy for children	-28.6080	8.0061	***
dummy for children aged less than 2	14.2630	7.0793	**
number of people in employment age	8.6977	5.3218	**
household size	1.7073	4.2183	
b_3T_1	9.1147	11.5350	
b_4: male health status: good	-0.0964	2.0988	
male age	0.0305	0.5018	
male employed in a firm	0.1237	1.0694	
male qualification: university 1st degree	-3.1962	5.0903	
female age	-0.2025	0.5160	
dummy for children	20.8110	7.0391	***
dummy for children aged less than 2	-11.6770	6.9402	**
number of people in employment age	-4.0455	4.6458	
household size	-3.4528	3.8210	

Table 14
The restricted model - continued-

Parameters	Estimates	St. errors	p
b_5	-0.0648	0.0935	
b_6	-0.0648	0.0935	
b_{5-6}	-0.0648	0.0935	
b_7	-10.7870	4.5081	***
b_8	-10.7870	4.5081	***
b_9	0.2482	0.1712	*
b_{10}	6.1042	1.9058	***
b_{11}	26.2830	21.6140	*
λ	-5.7007	2.1030	***
n = 513			
$R^2 = 0.2655$			

Table 15 reports female labour supply elasticities to wages (η_{H_2,w_2}, η_{H_2,w_2}), household non labour income ($\eta_{H_2,Y}$), female monetary and time transport costs

(η_{H_2,p_2} and η_{H_2,τ_2} respectively) and male monetary and time transport costs (η_{H_2,p_1} and η_{H_2,τ_1} respectively). These figures have been computed for each observation by using the appropriate estimated value of the parameters as well as the data appearing in the elasticity formula; the individual elasticity values have then been averaged across all the workers in the sample. In the table, the mean and standard deviation are given.[11]

Female labour supply is positively sloped and exhibits a positive elasticity with respect to the male wage rate and negative elasticity with respect to the household non labour income.

Women's labour supply is negatively affected by increases in transport costs; however, the impact is very tiny and has the opposite sign to that of female travel times.

Table 15
Female labour supply elasticities

	Mean	St. deviation
η_{H_2,w_2}	0.1546	0.1263
η_{H_2,w_1}	0.4000	0.3268
$\eta_{H_2,Y}$	-0.0180	0.0254
η_{H_2,p_2}	-0.0259	0.0211
η_{H_2,τ_2}	0.4056	0.3559
η_{H_2,p_1}	-0.0305	0.0249
η_{H_2,τ_1}	0.0307	0.0251

7 Conclusions

This paper has focused on the estimation of labour supply and modal choice for travel to work by the secondary worker both in the unitary and in the collective setting of household decisionmaking.

The empirical specification adopted allows us to quantify the correlation

[11] For example: the elasticity of female labour supply to unearned income has been defined as: $\eta_{H_2,Y} = \frac{\delta H_2}{\delta Y}\frac{Y}{H_2}$ which for observation i is given by: $b_5 * \frac{Y_i}{H_{2i}}$.

between the labour participation decision and the method used for work trips and showed that in fact such correlation is highly insignificant. However we do find evidence supporting the hypothesis that car usage strongly depends on car ownership, the results suggest that investigation should be devoted to the links between labour participation and the car ownership decision. One issue that we have not explored is intrahousehold decisions about who gets to use the car if a single car is available. We have also selected out households where the car use is shared for a given work trip by each individual.

The estimation of an unrestricted model of labour supply and the subsequent tests of parameter restrictions lead us to reject the unitary model and to accept a partial income pooling hypothesis, according to which individuals' non labour incomes and individuals' monetary transport costs define two separate sets of variables each affecting with different coefficients the secondary worker's labour supply. On the other hand, pooling was rejected for individuals' time travel costs. It is perhaps as if the household groups income and expenditure items eg household work travel costs and each individual uses information on these grouped items in their own decisions. But overall there is not full financial pooling.

The analysis conducted so far assumed fixed travel costs; an interesting extension would include variable transport costs. Due to the ineteraction between travel mode and the net marginal wage rate in this case, this would require a discrete choice type of approach.

Appendix 1

This Appendix reports the results of the regression run to estimate the husband's wage (table A1), the univariate probit estimates for female labour force participation (table A2), and the wife's wage estimates (table A4).

Table A1
Estimates of the husband's wage (by truncated regression)

Variables	Estimates	St. errors	p
Constant	1.2011	1.6370	
Age	0.2976	0.0666	***
Age squared	-0.3278E-02	0.75857E-03	***
Health status: good	0.3787	0.4895	
School leaving age	-0.0137	0.0303	*
Qualifications: university 1st degree	0.7964	1.7951	*
Employed in a private firm	0.08101	0.2397	
Work location: employer premises	0.7274	0.2089	***
Age*London	-0.0551	0.0295	**
London	3.7862	1.2877	***
Scotland	-0.7377	0.3435	**
Wales	-1.0905	0.4386	***
East Anglia	-1.1051	0.5390	**
East Midland	-0.9338	0.3585	***
Unemployment rate	-0.2630	0.0663	***
σ	2.3637	0.0689	***
n = 726			
Log likelihood function = -1627.237			

Table A2
Univariate Probit Estimates for labour force participation.
Reduced form.

Variables	Parameter estimate	Standard error	p
constant	-3.0505	1.1648	***
household non labour income	-0.1790E-02	0.1434E-02	
female non labour income	-0.0142	0.2289E-02	***
number of children aged: 0 - 2 years	-0.3963	0.1539	***
3 - 4 years	-0.6669	0.15835	***
5 - 11 years	-0.0344	0.0862	
12 - 15 years	0.3770	0.1263	***
couple no dependent children	0.4417	0.1547	***
detached and semi-detached house	-0.1533	0.1282	
mortgaged house	0.3659	0.1332	***
female age	0.1567	0.0506	***
female age squared	-0.2150E-02	0.6049E-03	***
female health status: good	0.5897	0.1990	***
female school leaving age	0.0290	0.0348	
husband's current job: civil servant	-1.0384	0.7277	*
access car usage by female	0.8034	0.1277	***
regional unemployment rate (%)	-0.0149	0.0386	
East Anglia	-0.3994	0.3186	
London	0.2678	0.2228	
North metropolitan	-0.3127	0.3303	
Wales	-0.4244	0.2547	**

In order to evaluate the goodness of fit of the univariate probit, Table A3 gives the frequencies of actual and predicted outcomes:

Table A3
Actual and predicted outcomes

	Predicted		
Actual	0	1	Total
0	190	125	315
1	62	462	524
Total	252	587	839

As shown by table A3, the percentage of correctly predicted outcomes amounts to about 75 percent for the non worker subsample and to 79 percent for the worker subsample.

Finally, table A4 shows the OLS estimation results for the prediction of female wage, where the inverse of the Mill's Ratio obtained from the univariate probit for labour participation has been added as an additional regressor:

Table 4

Estimates of the wife's wage (by Heckman model)

Variables	Estimates	St. errors	p
Constant	4.6367	2.1090	**
Age	0.4315	0.1776	***
Age squared	-0.5632E-02	0.2563E-02	**
Female school leaving age	-0.5835E-02	0.4346E-02	*
Experience	-0.3816	0.1320	***
Experience squared	0.4872E-02	0.1924E-02	
Female qualifications: university 1st degree	0.4999	0.8859	
Employed in a private firm	-1.0102	0.2732	***
Male school leaving age	-0.0414	0.3046	*
Male qualifications: university 1st degree	1.7827	1.5110	
North non metropolitan	-0.4829	0.4332	
Household non wage income	0.5608E-02	0.3596E-02	*
Male wage	0.1005	0.0254	***
South West	-0.6773	0.4532	*
West Midland metropolitan	-0.7416	0.6083	
Density	0.0233	0.67563E-02	***
Unemployment rate	-0.1492	0.0740	**
Inverse of Mill's ratio	-0.3575	0.2103	**
n = 401			

$R^2 = 0.1708$

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