INDIVIDUAL DOMESTIC PRODUCTIVITY AND TIME ALLOCATION WITHIN A HOUSEHOLD

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Abstract

The allocation of time is a crucial decision that influences many aspects of household welfare. According to standard theory it depends on the potential wage rate of spouses relative to their domestic productivity. A major problem, however, is that individual productivities are not observed. As a consequence, an important source of difference in household living standards alongside with heterogeneity in preferences and wage rates, cannot be accounted for.

This paper presents a new methodology to estimate individual domestic productivity based on the informational content of a standard time use survey, with time inputs observable but domestic output immeasurable. It provides empirical evidence based on a sample of French two-earner couples.

As a test of the empirical validity of this approach, the paper shows that the estimate of female domestic productivity is a significant variable in explaining the overall intra-household distribution of resources.

JEL Classification: D13, J22
Key words: Home production, time- use, collective models.

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1. Introduction

The allocation of time is a crucial decision that influences many aspects of household welfare. This is true, in particular, of the allocation of household members' time among market and domestic activities. Although on average in western countries, women devote more than half of their working time to domestic production, large variations are typically observed along the income scale. Women tend to spend more time in the labour market in the upper end of the distribution of 'full-time' income, whereas they devote more time to basic domestic activities in the lower end.

Although the role plaid by domestic production has been fully recognised by economic theory since the seminal paper of Becker (1965), nevertheless, the empirical literature in this field is still little developed. Empirical analysis of household time allocation is usually limited to the choice between paid 'working time' and 'leisure', combining in the latter both true leisure and time spent by household members in domestic production. This gap appears to be due to the lack of detailed information on the use of time by each household. Yet, the same gap can now be filled with the increasing availability of time use surveys in several countries.

The difficulty is not exclusively confined to the issue of time inputs being observable. Data on outputs and on the relative price of domestically produced goods with respect to market goods is equally crucial to understand time allocation. As far as the latter is concerned, a key assumption in theoretical models is whether domestic goods are substitute for market goods[1]. If they are imperfectly so, which is the assumption made in the Becker model, the price of domestic good is endogenous and varies in some unobservable way across households. In effect, this case has been criticized by Pollak and Wachter (1975) who argued that the price may even vary for each household by the consumption bundle chosen; the only exception is the assumption of constant returns to scale in domestic production. Yet, such assumption seems restrictive.

The alternative case, instead, with domestic production substitute for market goods is less restrictive as the price for domestic goods is exogenously fixed at the market level. Farm-households are the most appropriate example, as they produce and sell on the market. (Singh, Squire and Strauss, 1986 were the first to consider it). The

[1] See Apps (2003) for a complete discussion on this issue.

same framework is applicable to households in advanced economies as nearly every domestic activity could be substituted with a market good of a similar quality.

Deciding on what is the most justified assumption on the substitutability between domestic and market goods, requires the knowledge of not only time inputs into domestic production but also outputs. Outputs are rarely observed though[2], so that there will remain for some time something arbitrary in the assumptions unless market and domestic good substitutability is considered.

In this paper we show that under the assumption of perfect substitutability, it is possible to recover, from time use data and market earning rates, information on individual domestic productivities, and of course total domestic output. To our knowledge this is the first paper providing some indirect estimate of domestic productivities.

The availability of a measure of domestic productivity allows to more detailed tests about intra household decision making and in particular the allocation of working time between domestic and market activities and across spouses.

The idea that this allocation depends on individual bargaining power within a household is not new. It was already explored by Apps and Rees (1997) and Chiappori (1997) within the framework of the so-called 'collective' – or Pareto-efficient- intra-household model of time allocation. Under this assumption, and in the absence of consumption externalities across spouses, decision about the time allocation between domestic and market activities may be decentralized. Each spouse makes his/her choice on the basis of the prices he/she faces and a 'sharing rule' of full-time income within the household, that reflects relative bargaining powers.

Chiappori (1997) theoretically shows that if domestic goods are substitute for market goods, then it is possible to retrieve from the observation of time use data the production function of domestic goods up to a multiplicative constant, and the intra-household sharing rule up to an additive constant[3].

In addition to providing indirect estimates of domestic productivities this paper offers a test for some of the hypotheses derived from the collective model of intra-

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[2] Even when both time use and household consumption levels are observable, Browning and Gortz (2005), show that combining the two types of information leads to ever difficulties

[3] The results holds true with a non increasing return to scale production function (see Rapoport, Sofer and Solaz, 2003).

household allocation of consumption, leisure, market and domestic working time among households.

The rest of the paper is organised as follows. Section 2 introduces the theoretical framework and presents the assumptions necessary for the identification of domestic productivity. In Section 3 a functional form is chosen for home production that permits estimating domestic productivities. The main characteristics of the sample of French households are reported in Section 4. Results of the indirect estimation procedure of women's productivity are also discussed in that section. Finally, Section 5 presents a model for the estimation of intra-household allocation of goods, market and domestic time and applies it to the data set, including domestic productivity estimates. Section 6 concludes.

2. The collective model with domestic production

In this paper we consider the basic 'collective' model of consumption and leisure allocation in presence of domestic production with no public consumption and no externality between partners. If domestic and market goods are perfect substitutes, this model may be expressed as follows:

$$\begin{aligned}
&\max_{C_i, l_i, L_i, t_i} \theta U_m(C_m, l_m) + (1-\theta) U_f(C_f, l_f) \\
&s.t. \sum_i C_i \leq y + w_m L_m + w_f L_f + h_m(t_m, \pi_m) + h_f(t_f, \pi_f) \qquad \text{with } i = m,f \qquad (1) \\
&l_i + L_i + t_i \leq T_i
\end{aligned}$$

Individual preferences, U_i, for the male *(i=m)* and female *(i=f)* member of the household are defined over private consumption of a composite good C_i, which includes both market and domestic goods, and pure leisure l_i. Individual leisure can be obtained from the time constraint in the last equation of (1) where time for home production is t_i and labour market time L_i, total time available being T_i.. Savings are ignored so that income and consumption coincides. The budget constraint then defines total household consumption as the sum of aggregate non-labour income, y, market labour incomes, $w_i L_i$, where w_i stands for the wage rate of individual i, and the market value of total home production. The latter is generated separately[4] by both spouses according to the production functions $h_i(\,)$, $i = m, f$. The price of the composite market good C_i and its domestic substitutes is normalised to unity. Production functions are increasing in two individual specific arguments, i.e. the individual time inputs t_i and individual domestic productivity π_i. Moreover, it will be reasonably assumed that the marginal product of labour in domestic production is decreasing with time t_i.

In (1) θ is a weighting factor assigned to individual preferences with a value in the closed interval [0,1]. Two alternative assumptions can be made on θ. If it is a constant term, independent of individual characteristics, then problem (1) can be inserted in the traditional "unitary" approach to household decision modelling. A more general framework is provided by the "collective" view[5], where θ is a function of exogenous individual and household attributes, such as non labour income y and distributional factors including the relative value of individual wage rates w_i. Denoting non-wage *distributional factors* by $\boldsymbol{\kappa}$, the weighing factor θ can be written as a function $\theta(y, w_m, w_f, \boldsymbol{\kappa})$.

Solving out problem (1) proves that optimal decisions over time use depends on preferences, technology in the domestic production activity, wage rate and non-labour income. A simpler form can be obtained from using the *recursivity property* coming from the full substitutability of market and domestic goods –i.e. the separability of the budget constraint with respect to t_i, $i = m, f$. In effect, problem (1) can be solved in two-stages. Defining $\tilde{L}_i = L_i + t_i$ as total labour time, (1) can be re-written as follows:

$$\begin{aligned}
&\max_{,x_i,z_i,l_i} \theta U_m\left(C_m, T_m - \tilde{L}_m\right) + (1-\theta) U_f\left(C_f, T_f - \tilde{L}_f\right) \\
&s.t. \sum\nolimits_i C_i \le y + w_m \tilde{L}_m + w_f \tilde{L}_f + \sum\nolimits_i P_i^* \\
&t_i^* \le \tilde{L}_i \le T_i \quad i = m, f
\end{aligned} \tag{2}$$

where P_i* and t_i* are the solution to the profit maximization problem:

[4] We exclude cases of joint production, i.e. of production technologies that depends in a non-separable way on both partner time inputs.

[5] See Bourguignon and Chiappori (1992), Browning and Chiappori (1998) or Browning, Bourguignon and Chiappori (2006)

$$P_i^* = \max h_i(t_i, \pi_i) - w_i t_i \qquad \textit{with } i=m,f \tag{3}$$

A first result of this paper is the indirect estimation of individual productivity from the observation of time use. This result is derived from the second stage maximization problem (3). The first order condition of that problem writes:

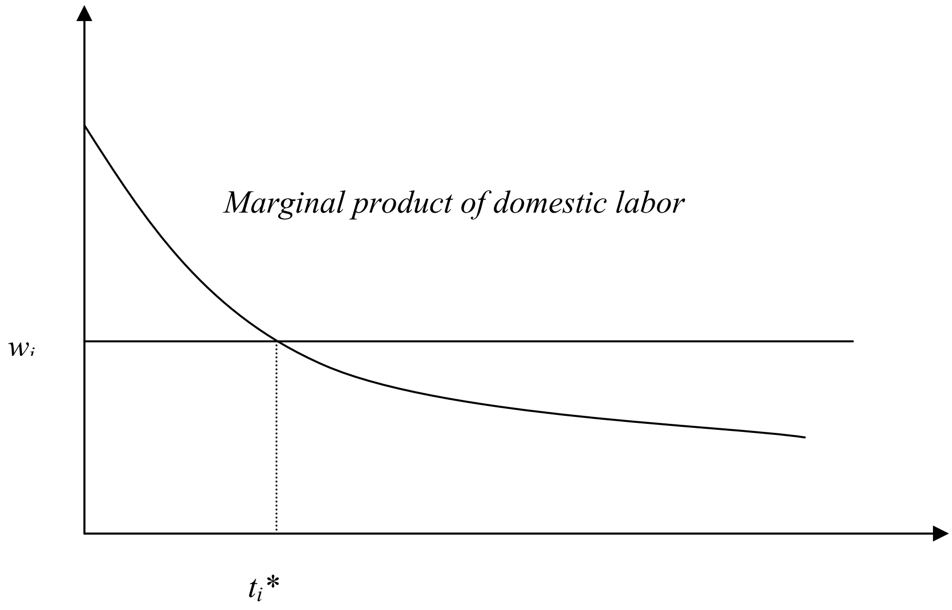
$$\begin{aligned} & t_i^* = 0 \qquad \textit{if } \frac{\partial h_i(0, \pi_i)}{\partial t_i} < w_i \ ; \\ & \frac{\partial h_i(t_i^*, \pi_i)}{\partial t_i} = w_i \ \ \textit{otherwise} \end{aligned} \tag{4}$$

Without very much loss of generality it can be assumed that both partners always do some work at home, whatever wage they can obtain on the labour market. Assuming decreasing returns to domestic time, this is equivalent to assuming that $\partial h_i(0, \pi_i) / \partial t_i \to \infty$. Then, the optimal domestic time of member *i* is given by the second part of condition (4). A graphical representation of that condition and the determination is given in Figure 1.

Denote h_{it} as the first derivative of *h* with respect to t_i. Under the assumption of decreasing marginal returns, the maximization problem (3) has a unique solution, $t_i^* > 0$. Reasonably assuming that the marginal product of domestic time is increasing everywhere with productivity, the second part of condition (4) can be inverted with respect to π_i. Denoting $h_{it}^{\pi -1}(t_i, w_i)$ the inverse of the marginal product of domestic labour with respect to productivity, it comes then that:

$$w_i = h_{it}(t_i^*, \pi_i) \quad \Leftrightarrow \quad \pi_i = (h_{it}^{\pi})^{-1}(t_i^*, w_i) \tag{5}$$

Figure 1 Optimal decision over domestic labour time when the recursivity property holds.



In other words, under the assumption that the marginal product of labour is positive, infinite at zero, decreasing with respect to labour but increasing with respect to productivity, domestic productivity may be recovered from the observation of labour time and the wage rate.

The recursivity property, associated with the perfect substitutability of domestic and market goods, insures that this property is independent of the intra-household allocation of total labour time and consumption. The latter can then be obtained from the first stage maximization in (2) with :

$$P_i^* = h_i(t_i^*, \pi_i) - w_i.t_i^*$$

3. Econometric procedure for the identification of individual domestic productivity

In what follows, we use the following specification of the domestic production function for member *i* of household *j*:

$$h_{ij}\left(t_{ij},\pi_{ij}\right)=\left(a_i t_{ij}+\pi_{ij}\right)^{\gamma_i}$$

with $\gamma_i \in [0,1]$ $(i=m, f)$ and $j=(1,..n)$ (6).

In that specification, a_i may be interpreted as the mean productivity of domestic labour for members of type i and π_{ij} as an idiosyncratic contribution to domestic production by member i in the household j. The coefficient γ_i permits the concavity of domestic production.

By solving problem (3) under the requirement that the domestic production is of type (6), it is possible to find that the first order condition (FOC) leading to a positive time spent in domestic production, whenever he/she also works, is:

$$\gamma_i a_i \left(a_i t_{ij}+\pi_{ij}\right)^{\gamma_i -1}=w_{ij} \tag{7}$$

i.e. the condition that equalises individual's marginal domestic productivity (in monetary value) to his/her wage rate. According to the efficient condition (7), allocating working time to home production for a given level of labour market time, would depend on both individual domestic productivity and the salary level.

As already shown in Section 2, condition (7) can be solved out to find the optimal level of time t_{ij} assigned by each individual in a couple to home production, that is:

$$\begin{cases} t_{ij}=0 & \text{if} \quad a_i \leq 0 \\ t_{ij}=A_i w_{ij}^{\left(\frac{1}{\gamma_i -1}\right)}+B_{ij} & \text{if} \quad a_i > 0 \end{cases} \tag{8}$$

after defining $A_i=\gamma_i^{\left(\frac{1}{1-\gamma_i}\right)} a_i^{\left(\frac{\gamma_i}{1-\gamma_i}\right)}$ and $B_{ij}=-\dfrac{\pi_{ij}}{a_i}$.

Substituting solution (8) into (3), we find that the optimal domestic production level is:

$$P_{ij}^{*}=\frac{1}{\gamma_i}\left(\frac{w_{ij}}{a_i}\right)^{\frac{\gamma_i}{\gamma_i -1}}-\frac{w_{ij}\pi_{ij}}{a_i} \qquad \text{if} \quad t_{ij}>0 \quad \text{for } i=m,f \quad \text{and} \quad j=(1,..n) \tag{9}$$

which is independent of π_{ij}.

As far as the identification of individual domestic productivity is concerned, from condition (7) we know that π_{ij} could be in principle identified from the observed individual wage rate, when $t_{ij} = 0$. Alternatively, for $t_{ij} > 0$, π_{ij} can still be retrieved after introducing some heterogeneity in the model. In particular, the following steps show how the home production function can be estimated through the first order condition (8) when heterogeneity is imposed on the slope coefficient a_i and on the intercept term π_{ij}.

Introduce heterogeneity in a_i by rewriting this coefficient as:

$$a_i = \bar{a}_i \left(1 + \varepsilon_{ij}\right) \tag{10}$$

where ε_{ij} is distributed as $N\left(0, \sigma_{\varepsilon}\right)$. Then, the hour equation rewrites as:

$$t_{ij} = \left[\bar{a}_i \left(1 + \varepsilon_{ij}\right)\right]^{\frac{\gamma_i}{(1-\gamma_i)}} \gamma_i^{\frac{1}{1-\gamma_i}} w_{ij_i}^{\frac{1}{(\gamma_i - 1)}} - \frac{\pi_{ij}}{\bar{a}_i \left(1 + \varepsilon_{ij}\right)}$$

Considering that the second term may be rather small and taking first order approximations, the home production labour supply may be re-written as :

$$t_{ij} = \bar{A}_i w_{ij}^{\left(\frac{1}{\gamma_i - 1}\right)} + \bar{B}_{ij} + \varepsilon_{ij} \left[\frac{\gamma_i}{\gamma_i - 1} \bar{A}_i w_i^{\left(\frac{1}{\gamma_i - 1}\right)} - \bar{B}_{ij} \right] \tag{11}$$

with $\bar{A}_i = \gamma_i^{\left(\frac{1}{1-\gamma_i}\right)} \bar{a}_i^{\left(\frac{\gamma_i}{1-\gamma_i}\right)}$ and $\bar{B}_{ij} = -\frac{\pi_{ij}}{\bar{a}_i}$.

Let us now introduce observed heterogeneity in $\bar{B}_{ij}$:

$$\bar{B}_{ij} = X_{ij}'\beta_i + \eta_{ij} \tag{12}$$

where η_{ij} is an error term, orthogonal to ε_{ij}, which follows $N\left(0, \sigma_{\eta}\right)$ distribution and which captures also some measurement errors. Due to the recursivity property discussed in Section 2, condition (12) allows us to instrument π_{ij} on a vector of individual specific characteristics X_{ij}.

Finally, putting (11) and (12) together (ignoring the product of residual terms $\varepsilon_{ij} \cdot \eta_{ij}$), the structural form for individual domestic production time becomes:

$$t_{ij} = \bar{A}_i w_{ij}^{\frac{1}{\gamma_i - 1}} + X_{ij}'\beta_i + \varepsilon_{ij} \left[\frac{\gamma_i}{\gamma_i - 1} \bar{A}_i w_{ij}^{\frac{1}{\gamma_i - 1}} - X_{ij}'\beta_i \right] + \eta_{ij} \tag{13}$$

Model (13) is non -linear in γ_i. It also exhibits heteroskedasticity with some restrictions linking the expected value of t_{ij} and the standard deviation of the error terms. Therefore, equation (13) could be estimated using maximum likelihood techniques (ML). The derivation of the log likelihood function is reported in Appendix 1.

Using definition (12), the fitted value of π_{ij} will be given by the condition:

$$\hat{\pi}_{ij} = \hat{\bar{a}}_i \cdot (X_{ij}'\hat{\beta}_i) \quad (14).$$

. 4. Measuring individual domestic productivity for a sample of French households

The data-set used in this study is the INSEE (1999) survey Enquête Emploi Du Temps 1998-99, which is the broadest experiment ever conducted in France of data collection of household time use. It includes information on main demographic characteristics, labour supply, incomes and use of time for a sample of 8,186 French households (20,370 individuals). Data on the use of time were collected for household members 15 years old or older (15,441 individuals in 7,949 households); they received and filled a booklet reporting information on the use of time in minutes in a weekly day. The potential of the survey is clear-cut once it is compared with a previous time use survey by INSEE, collected in 1986, which had the limit of providing time use information on one member per household, rendering it useless for our study.

Being interested in analysing couple's time allocation process, we only consider households whose head lives in couple (corresponding to 64.75 percent of the total sample). Moreover, we also select those households with head and spouse being 25-60 years old. As our framework does not raise retirement and unemployment issues, we exclude households with couple members being either retired or unemployed; moreover, under the assumption that income variables might not be reliable, we do not consider families with head or spouse being self-employed.

To begin with, we disregard use of time on holidays or during the weekend, as time use in spare time might be driven by significantly different purposes. Therefore, a further selection (2,482 households, about 56 percent of the selected sample) considers family members interviewed in working days only. Later on, however, as a sensitivity analysis, we empirically test whether our approach extends to the allocation of time over the weekend.

Finally, 31 percent of the selected sample reported missing income variables, and as a consequence we disregard them. Thus, the final sample of our study has 674 observations and its main characteristics are reported in Table 1.

In the survey the description provided for each line of activity is very accurate: it contains duration, place and activity type (classified in about 90 codes). Following INSEE (2000) we recode the reported activities into six main categories:

a) personal time,
b) domestic time,
c) child care,
d) market working time,
e) travel time,
f) leisure[6].

[6] In particular, personal time includes sleeping, self-care, private activities or eating; home-production time adds up minutes spent in cooking, cleaning, sowing, washing, doing shopping or gardening. The category of child care includes time spent playing with children whereas market working time comprises paid work also if done at home, training, learning and time breaks. Leisure considers various types of entertainment as sports, reading, cinema, listening music, watching TV, relaxing, and social activities as voluntary work, religious practices and telephone conversations.

Table 1 Descriptive statistics for couples

	no.	mean	std. dev.
(1) Household Characteristics			
Household without children (a)	166	0.25	
Number of children: (a)	508	2.00	1.02
Geographical area:			
North	674	0.08	
East	674	0.12	
Central-east	674	0.10	
Centre	674	0.24	
Parisian Region	674	0.13	
West	674	0.18	
South-west	674	0.10	
Mediterranean	674	0.10	
Home- ownership status	674	0.63	
Total weekly unearned income (b) (c)	674	79.99	185.69
(2) Men Characteristics			
Age	674	42.34	9.10
Education: Primary school	674	0.25	
Secondary school	674	0.13	
Univ. and post-grad. Degrees	674	0.27	
Employment Characteristics: Participation	674	0.91	
Weekly contract hours of work	612	37.95	4.89
Net hourly wage (b)	612	10.03	6.35
(2) Women Characteristics			
Age	674	39.99	8.73
Education: Primary school	674	0.27	
Secondary school	674	0.16	
Univ. and post-grad. Degrees	674	0.28	
Employment Characteristics: Participation	674	0.64	
Weekly contract hours of work	432	33.34	9.25
Net hourly wage (b)	432	8.31	4.89

Note: (a) the number of positive observations only is reported.
(b) Nominal variables in Euro
(c) Unearned income is a derived variable from total household income net of couple's labor income.

Table 2 contains some descriptive statistics on the percentage of time devoted to each activity in a day by each spouse. Men devote most of their working time on the job, whereas time is almost equally shared between paid and unpaid work for women.

Another interesting picture concerning time use comes out of Table 3 which contains the statistically significant correlation matrix across spouse activities. As we could expect, there is a high complementarity in working time between spouses, proven by a positive correlation (0.2) between their market working time and by a negative correlation between individual leisure and partner's working time. Similarly individual leisure is also positively correlated with the spouse one. There is instead no evidence of joint domestic production (in line with our assumption of separability in the production function), rather women time for home production is positively correlated with men's leisure.

Table 2 Couple's time use

	mean	std. dev.
Men daily time use (in percent)		
Duration of personal time	0.44	0.08
Duration of market working time	0.31	0.12
Duration of home production time	0.06	0.07
Duration of leisure	0.13	0.09
Duration of travel time	0.05	0.04
Duration of child care	0.01	0.02
Women daily time use (in percent)		
Duration of personal time	0.43	0.07
Duration of market working time	0.20	0.16
Duration of home production time	0.19	0.12
Duration of leisure	0.11	0.08
Duration of travel time	0.04	0.04
Duration of child care	0.03	0.06

Note: Each distribution refers to the selected sample of 674 households.

Table 3 Correlation indexes across spouses' use of time

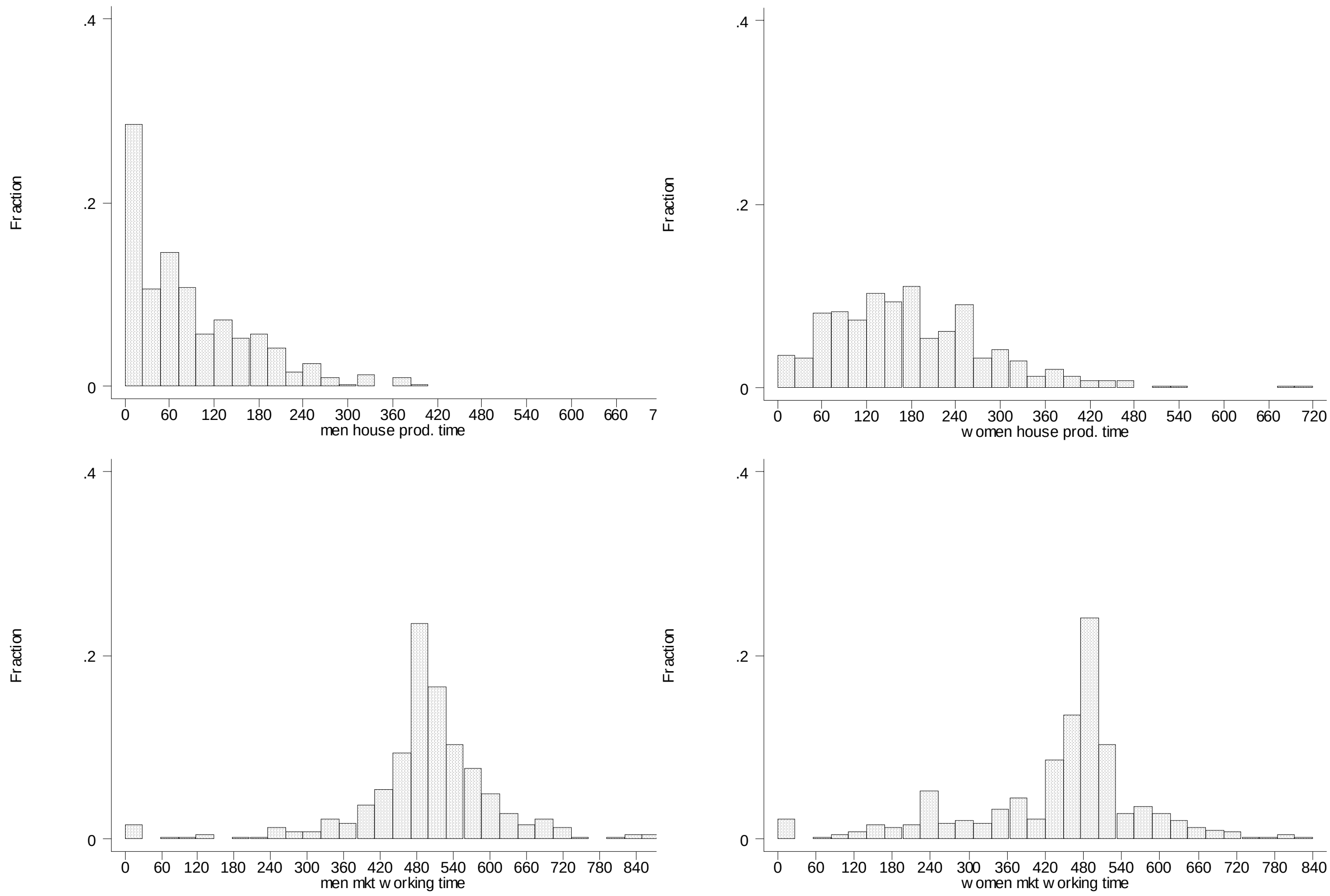
MEN WOMEN	*Market working time*	*Home production time*	*Leisure*
Market working time	0.197 *	-	-0.223 *
Home production time	-	-	0.091
Leisure	-0.205 *	-	0.350 *

Note: Only correlation indexes significant at the 95% level are reported
* Significant at the 99% level.

Figure 2 describes the distribution of working (market and non market) activities (in minutes) for the sample of households with both spouses participating to the labour market. More than half of the sample of men reports zero time or less than an hour per day time devoted to domestic production. As expected individual market working time in both cases peaks at 8 hours, the so-called "contract hours".

Finally, consider that market working time and home production of each partner are negatively correlated (-0.8 for women and -0.5 for men).

Figure 2 Intra household allocation of time – Sample of two-earner households



Following the theoretical analysis described in Sections 2 and 3 we carry out the estimation of individual domestic productivity on the sample of individuals that work on the labor market and produce domestic goods by means of a two step procedure, which allows to correct for sample selection bias.

Our empirical evidence shows that men and women view the problem of time allocation from different perspectives. Women, given their domestic technology, their preferences for consumption and leisure and share of income, optimally allocate their working time between the labour market and domestic good production. Men instead ultimately consider as an option domestic production. Such underlining evidence will drive our research strategy to estimate individual domestic productivities, as it will follow two distinct directions.

In particular, in order to estimate women domestic productivity we introduce a latent variable I_{fj}^* capturing, in reduced form, the joint female participation decision to the labor market and to domestic production. I_{fj}^* is defined as a linear function of:

$$I_{fj}^* = f(Y_j, X_{fj}) \qquad \text{with } j=1,\dots n \tag{15}$$

where the vector X_{fj} contains a set of individual characteristics (age, education etc.) whereas Y_j is a vector of household characteristics.

We also construct a dichotomous variable I_{fj} such that $I_{fj} = 1 \Leftrightarrow I_{fj}^* \geq 0$ and $I_{fj} = 0 \Leftrightarrow I_{fj}^* < 0$; this indicates the alternative chosen. From Heckman (1979), we know that the full log-likelihood function of our model can be estimated in two-steps, i.e. with:

a. a preliminary estimation of a probit equation for the joint decision to participate to the labor market and spend a positive amount of time for domestic production, in reduced form;
b. the estimation of women time devoted to home production using the structural form (13) and controlling for selection bias involved in the simultaneous choice of working and producing domestic goods by including the inverse of the Mill's ratio λ_{fj}, obtained from the first stage estimation.

Empirical estimates of the first step are presented in Table 4. Among the household characteristics included in the regression, the joint decision is mainly affected by a non linear function of age; also the higher is household non labor income the less likely the woman combines paid work with the domestic one. Instead a higher investment in education provides strong incentives for a woman to work more. Finally, playing the role of a demand factor for home production as an exclusive activity, the number of children has a discouraging impact, with an additional effect when they are 0-3 years old.

Table 4 The probability for a woman jointly participating to labor market and producing domestic goods

Variables			
Woman's age	0.422	(0.077)	***
Woman's age ^{2}	-0.005	(0.001)	***
Non labor income	-0.002	(0.000)	***
Man's Wage	-0.008	(0.010)	
Woman Educational Dummies: Bac technique	0.606	(0.274)	**
Bac +2	0.429	(0.197)	**
Univ. and post-grad. degree	0.544	(0.220)	***
Number of children	-0.396	(0.062)	***
No. of children 0-3 years old	-0.499	(0.158)	***
Other adult	0.291	(0.385)	
City dummy: Paris	0.091	(0.168)	
Internet service at home	0.592	(0.263)	**
Constant	-6.746	(1.466)	***
Obs.		612	
		Pseudo R^2 =0.22	

(***: $p \leq 0.01$; **: $0.01 < p \leq 0.05$; *: $0.05 < p \leq 0.10$)

Note: In the table results of a probit estimation and standard errors in brackets. Reference categories for categorical variables: women with a degree CAP/BEP or Bac general and not living in the capital.

Results from the second step, i.e. the estimation of women time devoted to home production, are reported in Table 5. In support of the non-linear function of wage, derived from the marginal condition (7), both the estimated coefficients for $\overline{A}_f$ and γ_f are consistent with a decreasing return to scale production function and satisfy the negative relation between the time devoted to domestic production and the wage rate.

Table 5 Estimation of women time for domestic production

Variables			
$\overline{A}_f$	0.616	(0.189)	***
γ_f	0.389	(0.103)	***
$\overline{B}_{fj}$: Constant	-0.148	(0.064)	**
Woman age	0.010	(0.003)	***
Woman age^2	-0.000	(0.000)	**
CAP/BEP school	-0.018	(0.007)	***
Bac technique	0.003	(0.012)	
Bac general	-0.034	(0.011)	***
λ_{fj}	0.016	(0.011)	
σ_ε	0.359	(0.142)	***
σ_η	0.000	(0.045)	
Obs.		401	
		$\log L$ =559.82	

Note: in the table results by ML estimation corrected for female participation to labor market and domestic production. Standard errors in parentheses. Reference category for categorical variables: Bac+2 and University and postgraduate degree.

The intercept term $\pi_{fj}/\overline{a}_f$ is instrumented with a polynomial function of age and three educational dummies. Recall that a result highlighted in Section 2 is that optimal time devoted to home production, when it is also efficient to offer paid work, is affected by individual characteristics only; this property is valid regardless of the framework adopted (unitary or collective). We find that women domestic productivity increases with age but at a decreasing rate, whereas lower education associates with lower domestic productivity, provided that the reference categories are higher degrees of schooling. A common negative constant term indicates a lower bound, i.e. a fixed cost, above which a positive value for domestic production can be obtained.

Given the estimation of the error term ε_{fj}, each parameter of the production function can be derived, as already stated in Section 3 and their statistics are reported in Table 6.

Table 6 Estimated coefficients of the woman domestic production function

Variable	Mean	Std dev	Min	Max
a_f	22.613	8.536	6.877	51.508
π_f	1.485	0.463	-0.053	2.136
γ_f	0.389	0.000	0.389	0.389

We also investigate whether the estimated values for π_{fj} significantly differ from the female wage rates: in particular, as a further check, we regress the latter on the same regressors used as instruments for π_{fj} and we find a high discrepancy in their distribution and a relatively low correlation coefficient (0.36).

As a sensitivity analysis, we also consider a more general model. In particular, instead of selecting only the sample of couples interviewed in working days, we also examine whether our model would determine how women in couple allocate their time between market work and home production during a whole week (weekend included).

Thus, let t_{fj} be the total hours of domestic production determined by the model, that is after equalizing the marginal product of hours of work with the wage rate. Consider two distinct values for t_{fj}, depending on the day of the interview. Let then t_{fj}^{wd} be hours of work for those people observed during a weekday and t_{fj}^{we} hours of work of people observed during the weekend.

Provided that $t_{fj}^{wd} = \psi \cdot t_{fj}$ and $t_{fj}^{we} = (1-\psi) \cdot t_{fj}$, with $0<\psi<1$, then a generalization of the model described in (13) - when both samples are considered - would imply the following for observed hours, t_{fj}^{o}:

$$t_{fj}^{o} = \psi \cdot D \cdot t_{fj} + (1-\psi) \cdot (1-D) \cdot t_{fj} \qquad \text{with } j=0,\ldots,n \tag{16}$$

where *D* is a dummy for being observed on a week-day and t_{fj} is defined in (13).

If a model of optimal week-time allocation as in (16) were a better representation for the household decision process, we would expect that women with a high salary should do less home production on week-ends, when they may have less constraint on their time.

However, results obtained estimating equation (16) by ML on a sample of 778 observations (401 couples interviewed on a week day and 377 over the weekend) were largely unsatisfactory. A plausible explanation is that, due to the constraints set by the market, a worker with a high wage will do more paid work during the week– i.e. when the market is ‘open’- and postpone more domestic work in the week-end. In other words, the model examined as first seems more appropriate, as it is derived under the assumption that the optimal allocation of time between paid and unpaid work is valid only on week-days, since the time to be spent on home production during week-ends cannot be determined by the wage rate; rather it should result from some optimal allocation between pure leisure and home production. Thus we found that the dichotomy between production and consumption examined in this study for working women breaks down during the weekend.

On the basis of such evidence, we can conclude that an additional hour of domestic production is traded with market time, for a constant leisure, only on weekdays as on average women cannot go to work on week-ends and cannot postpone all domestic consumption to week-ends either. Overall, we consider this result as further evidence supporting our model of efficient allocation between home production and market working time during a week, but excluding the weekend.

Before turning to the labor supply estimation, we briefly discuss the lack of evidence found for men domestic production. Several attempts made with various sophisticated econometric specifications (as a non linear tobit model) were unable to provide convincing results. As a consequence we are not in the position to estimate men domestic productivity π_{mj}; thus we can conclude that time devoted to home production by men is only randomly chosen after their working time has been fixed by contract and they fall in the first extreme case of equation (8) with $a_m \leq 0$. In what follows we consider π_{mj} as a random component in the production function and in the household system of labour supply.

5. Individual domestic productivity and intra-household income distribution

A further aim of the paper is the analysis of the intra-household allocation of total working time. In particular, under the assumption of egoistic or caring preferences, problem (2) is equivalent to:

$$\begin{aligned} &\max_{C_i, l_i} U_i\left(C_i, T - \tilde{L}_i\right) \\ &s.t. C_i \leq w_i \tilde{L}_i + \phi_i \end{aligned} \qquad (i=m, f) \qquad (17)$$

where ϕ_i is member *i* share of total income, including domestic production. In other words, in the literature of collective household models ϕ_i is the so-called "income sharing rule" and in order for individual budget constraints to meet the total household income, the condition $\phi_m + \phi_f = y + P_i^* = \bar{y}$ has to hold.

The collective framework imposes certain further restrictions on the system of total labor supply, as it will be of the following type:

$$\begin{aligned} \tilde{L}_m &= \tilde{L}_m\left(w_m, \phi_m\left(w_m, w_f, \bar{y}, \pi_m, \pi_f, \mathbf{d}\right), \mathbf{d}\right) \\ \tilde{L}_f &= \tilde{L}^f\left(w_f, \bar{y} - \phi_m\left(w_m, w_f, \bar{y}, \pi_m, \pi_f, \mathbf{d}\right), \mathbf{d}\right) \end{aligned} \qquad (18).$$

Taken ***d*** as a vector of demographic variables affecting both individual preferences and the income share ϕ_i, we can show how the particular structure of system (18) imposes testable restrictions on the labor supply behavior and allows to recover the individual income sharing rule ϕ_m up to an additive function of ***d***, if at least one distribution factor can be observed. In particular, note that an important testable restriction has to do with the role here plaid by domestic productivities. In principle, individual domestic productivity affects a collective system of household total labor supply through two channels:

(i) the total non labor income $\bar{y}$,

(ii) the weighing factor θ (or, equivalently the income share ϕ_i).

In a standard unitary model instead, domestic productivities should have only affected total labor supply through unearned income only, which, in principle, already provides a new test of the unitary versus the collective model.

However, we already noted that, due to the functional form chosen, P_i^* in (9) is independent of the intercept π_i in the individual optimal domestic production level. In other words, we find that for internal solutions only, the requirement of efficiency in home production implies that the system of total labor time (18) depends on the individual domestic productivity parameter π_i only through $\phi_m(\cdot)$, thus fully satisfying the definition for a *distributional factor* already provided by the literature on collective models.

Although testing for the relevance of individual domestic productivity in the household labor supply might already provide a preliminary evidence against the traditional unitary model, it is yet not sufficient as a test for the collective model. As shown in CFL and other studies, it is the way in which the distribution factor π_i and the spouse' wage rate do affect the two labour supplies that enables us to test for a general collective model of labour supply.

Following CFL (their *Proposition 3)*, we can derive a set of necessary conditions for any pair of $(\tilde{L}_m, \tilde{L}_f)$ to be the solution of problem (17) for a given sharing rule ϕ_m. CFL show that observing one distribution factor and the individual wage rates is sufficient to impose a set of testable restrictions for a collective model on a system of labour supply and to recover the partials of the sharing rule with respect to total non labour income, each individual wage rate and the distribution factors π_i.

Thus, in order to derive a series of parametric tests, we compare the collective approach with an unrestricted system of household labour supplies, in line with the testing strategy developed in CFL. However, the novelty here stays in the fact that we apply it to a system of total labour supply $(\tilde{L}_m, \tilde{L}_f)$ as the sum of market working time and time devoted to domestic activities as solution of problem (3).

In order to provide testable restrictions for the collective model as earlier specified, consider the following household labour supply system:

$$\begin{aligned}\tilde{L}^m &= f_0 + f_1 \log w_m + f_2 \log w_f + f_3 \bar{y} + f_4 \log w_f \cdot \log w_m + f_5 \log w_m \cdot \bar{y} + \\ &\quad f_6 \log w_f \cdot \bar{y} + f_7 \pi_f + f_8 \pi_m + f_9 '(\mathbf{d}) \\ \tilde{L}^f &= m_0 + m_1 \log w_m + m_2 \log w_f + m_3 \bar{y} + m_4 \log w_f \cdot \log w_m + m_5 \log w_m \cdot \bar{y} + \\ &\quad m_6 \log w_f \cdot \bar{y} + m_7 \pi_f + m_8 \pi_m + m_9 '(\mathbf{d})\end{aligned} \tag{19}$$

System (19) has a semi-log functional form, and compared to the one used by CFL it allows more interactions in the variables. We call it *unrestricted* because no cross-equation restrictions are imposed; however, it does provide the nesting framework to test for a collective model[7].

Following CFL, we retrieve the necessary conditions for system (19) to be derived from a collective framework and we obtain three equality restrictions:

$$\frac{f_4}{m_4} = \frac{f_5}{m_5} = \frac{f_6}{m_6} = \frac{f_7}{m_7} = \frac{f_8}{m_8} \tag{20}$$

Note that if restrictions (20) are satisfied, then the income sharing rule parameters can be identified up to a constant, as the partials of ϕ_m are respectively:

$$\begin{aligned}\frac{\partial \phi_m}{\partial \bar{y}} &= \frac{m_5 \left(f_3 + f_5 \log w_m + f_6 \log w_f \right)}{\Delta} \\ \frac{\partial \phi_m}{\partial \pi_f} &= \frac{m_7 f_5}{\Delta} \\ \frac{\partial \phi_m}{\partial \pi_m} &= \frac{m_8 f_5}{\Delta} \\ \frac{\partial \phi_m}{\partial w_m} &= \frac{f_5 \left(m_1 + m_4 \log w_f + m_5 \bar{y} \right)}{w_m \Delta}\end{aligned} \tag{21}$$

[7] Although we disregard in this paper testing for the *unitary model*, still the framework could have handled it. In particular, if we were in a unitary model, whenever each spouse is favourable to participate to the labor market and to produce domestic goods, the household labor supply system (including both market and non-market working time), satisfies two sets of restrictions; they are the necessary and sufficient conditions for a household utility function to be maximised, subject to a household budget constraint:

a) the Slutsky matrix must be symmetric and positive semi-definite;

b) a further set of condition is due to the irrelevance of individual domestic productivities in the decision process.

$$\frac{\partial \phi_m}{\partial w_f} = \frac{m_5\left(f_2 + f_4 \log w_m + f_6 \bar{y}\right)}{w_f \Delta}$$

where $\Delta = m_5 f_3 - f_5 m_3$. Integrating the four differential equations system in (21) we can obtain the income sharing rule equation:

$$\phi_m = \frac{1}{\Delta}\left[m_5 f_3 \bar{y} + m_1 f_5 \log w_m + m_5 f_2 \log w_f + m_7 f_5 \pi_f + m_8 f_5 \pi_m + m_5 f_5 \log w_m \bar{y} + \right.$$
$$\left. + m_6 f_5 \log w_f \bar{y} + m_4 f_5 \log w_m \log w_f \right] + \tau \tag{22}$$

in (22) τ is an additive function of $(\mathbf{d})$.

Finally, note that the system of total labour supply associated with a collective setting is:

$$\begin{aligned} \tilde{L}_m &= \alpha_1 \log w_m + \alpha_2 \phi_m + \alpha_3 \\ \tilde{L}_f &= \beta_1 \log w_f + \beta_2\left(\bar{y} - \phi_m\right) + \beta_3 \end{aligned} \quad (23).$$

where $\alpha_1 = \left(m_1 f_5 - f_1 m_5\right)/ m_5$; $\alpha_2 = \Delta / m_7$; $\beta_1 = \left(m_2 f_5 - f_2 m_5\right)/ f_5$; $\beta_2 = -\Delta / f_5$.

In what follows we present the estimation results of the household labor supply, using as measure of working time the sum of market labour time and time devoted to domestic production.

A well-known drawback of market labour supply estimations, especially with European survey data, is that due to the rationing imposed by labour contracts, they usually do not seem to respond significantly to wages and income. This is particularly relevant for men labour supply (see Pencavel, 1986 for a survey). A preliminary empirical exercise highlighted that the quality of our estimations could remarkably improve when moving from market labour time to total labour supply, above all with men working hours, since with the former measure we found a very low significance level, as their market working time seems rigidly fixed at a constant level.

Under such premises, we estimate the household total labour supply by full information maximum likelihood (FIML). It provides efficient estimates of the parameters of the two simultaneous equations, since it can handle both plausible correlation between the error terms in the male and female labour supply and heteroskedasticity in the errors in an unknown form.

Another relevant consideration is that wage rates, and non-labour income, entering in the household labour supply system, are not exogenous to hours of work.[8] In order to overcome the potential endogenity problem, all variables are accurately instrumented with exogenous socio-demographic variables (individual age and educational level, also interacted), number of children with an additional effect when they are 0-3 years old, the presence of another adult co-residing, living in the city of Paris and an internet link provided in the house[9].

Following system (19), each labour supply equation also includes personal age in an exponential form, educational dummies and the presence of children 0-3 years old. Finally, female labour supply is corrected for selection bias, by adding in the labour supply equation the inverse of the Mills' ratio (λ_w) obtained from a previous estimation of her participation to the labour market; we use as extra identifying variables for women participation three regional dummies (detecting the household residence in the North, West, or Central- East of the country).

Table 7 lists coefficients and asymptotic standard errors obtained from the estimation of system (19). The husband total labor supply is affected negatively by his own wage rate and by a few demographic variables (in particular age, age squared, having a child 0-3 years old and higher educational dummies). The significance of the female domestic productivity term in the male labor supply equation already provides sufficient evidence against the traditional unitary model, as it has been clarified at the beginning of this Section.

Conversely, the woman's total working hours are affected by unearned income, not only directly, but also interacted with family wages, domestic productivity and the λ_w terms are both negative but not significant.

[8] There are various reasons for considering the two sets of variables as endogenous; in particular, for the wage rate, one should consider the so-called "division bias", since it is a derived variable (yearly after-tax labor earnings divided by the product of working weeks per year and working hours per week), and also the presence of unobservable components (e.g., preferences for work) which might influence both wages and hours. Even individual non-labor income could include endogenous components, as, for instance, it might well be derived from labor income savings.

[9] Results are available upon request to the authors. Individual wage estimates were not corrected for selection bias, as a preliminary investigation did not provide a better fit.

The second column of Table 7 contains the estimates of the collective system of total labor supply, i.e. once restrictions (20) are imposed. Overall signs and significance level are confirmed, also when the necessary collective restrictions hold.

The log-likelihood values obtained from the estimation of system (19), unrestricted and when the restrictions derived are imposed, are compared in Table 8, which reports the derived likelihood ratio statistics. On the basis of the evidence found, the parametric restrictions required by the collective model cannot be statistically rejected (LR test $\chi^2_{(3)}$ =4.685).

Empirical results from the estimation of the collective model is completed with the computation of the parameters and the asymptotic standard errors (obtained by 'delta method') of the income sharing rule (see Table 9, which contains also the partial derivatives in the second column). They imply that an increase in the husband's wage rate tends to reduce substantially his transfer to the wife, as well as an increase in the wife's wage rate, although the effect is smaller. These results suggest that women of our sample behaves more altruistically than men. An opposite result is instead found for changes in total unearned income: 100 € increase in non labor income will increase the wives' share by about 70 percent. So far, the signs of the income sharing rule parameters are consistent with those found by Chiappori Fortin and Lacroix, although our results have a higher significance level.

Table 7 The unrestricted vs. the collective model of household total labor supply

MEN	Unrestricted system	Collective Model
$\log \hat{w}_m$	-4.131 (2.615) *	-1.392 (1.241)
$\log \hat{w}_f$	-1.600 (2.031)	0.014 (0.628)
$\hat{\hat{y}}$	-0.071 (0.124)	-0.071 (0.156)
$\log \hat{w}_m \times \log \hat{w}_f$	0.770 (0.841)	-0.061
$\log \hat{w}_m \times \hat{\hat{y}}$	0.006 (0.048)	-0.021 (0.043)
$\log \hat{w}_f \times \hat{\hat{y}}$	0.0277 (0.088)	0.060
$\hat{\pi}_f$	-0.608 (0.314) **	-0.053
Man's age	0.429 (0.139) ***	0.287 (0.127) **
Man's age ^{2}	-0.004 (0.001) ***	0.003 (0.002) **
Man education: Bac general	0.736 (0.544)	0.574 (0.516)
Bac +2	1.258 (0.617) **	0.866 (0.559)
Univ. degrees	1.959 (0.915) **	1.485 (0.875) *
Child 0-3 years old	0.548 (0.269) **	0.576 (0.270) **
Constant	9.140 (5.047) *	6.403 (2.474) ***
WOMEN	**Unrestricted system**	**Collective Model**
$\log \hat{w}_m$	-0.526 (1.806)	-0.481 (1.847)
$\log \hat{w}_f$	0.450 (1.946)	0.499 (1.973)
$\hat{\hat{y}}$	-0.314 (0.119) ***	-0.311 (0.120) ***
$\log \hat{w}_m \times \log \hat{w}_f$	-0.256 (0.770)	-0.271 (0.790)
$\log \hat{w}_m \times \hat{\hat{y}}$	-0.094 (0.046) ***	-0.091 (0.050) *
$\log \hat{w}_f \times \hat{\hat{y}}$	0.268 (0.085) ***	0.263 (0.090) ***
$\hat{\pi}_f$	-0.076 (0.418)	-0.233 (0.598)
Woman's age	0.040 (0.023)*	0.048 (0.030) *
Woman education: Bac techn.	0.120 (0.366)	0.177 (0.373)
Bac general	-0.502 (0.412)	-0.629 (0.477)
Bac +2	-0.019 (0.255)	0.008 (0.262)
Child 0-3 years old	-0.363 (0.290)	-0.361 (0.292)
Constant	10.158 (4.308) **	9.946 (4.340) **
λ_w	-0.448 (0.376)	-0.460 (0.376)
	LogL= -1508.527; ρ=0.31	*LogL*= -1510.8693; ρ= 0.33

Note: FIML estimates of two simultaneous equation. Semi-log system of household total labor supply: sample of two earner couples (397 obs.). Coefficients without standard error are constrained.

Table 8 Likelihood ratio test

	Unrestricted Model	Collective Model
log L	-1508.527	-1510.869
LR (dof)	-	4.685 (3)

Note: Sample of households with both spouses working

The novelty of our approach allows us to measure the effect of female domestic productivity on the intra-household allocation of resources. According to our estimates, given an average productivity value of 1.485, a family with a one percentage increase in female domestic productivity would see men benefiting of 10.21 € increase in his total income share.

Table 9 Sharing rule estimates

	Coefficients	$\partial\phi_m / \partial$Variable
Log $\hat{w}_m$	1421.90 (457.48) ***	333.75 (221.34)†
log $\hat{w}_f$	-189.00 (171.83)	98.48 (120.33) †
$\hat{\hat{y}}$	919.53 (367.47)***	-71.97 (103.75)
$\hat{\pi}_f$	687.53 (318.26) **	687.53 (318.26) **
Log $\hat{w}_m \times$ log $\hat{w}_f$	798.06 (342.45) ***	-
Log $\hat{w}_m \times \hat{\hat{y}}$	269.09 (198.88)	-
log $\hat{w}_f \times \hat{\hat{y}}$	-775.90 (337.72) **	-

Note: Sample of households with both spouses working. Asymptotic standard errors, computed by delta method, in brackets.
† The derivatives are computed with respect to $\hat{w}_m$ and $\hat{w}_f$, respectively.

Table 10 allows to compare the uncompensated labor supply elasticities to changes in individual wage rates and non-labor income drawn from the unrestricted system with those obtained after imposing the collective restrictions. Under the collective specification, we obtain a negative uncompensated wage elasticity for the husband, showing a dominant income effect, and a small but positive value for wife, showing a prevailing substitution effect. This finding is consistent with previous international evidence on market labour supply (see Pencavel, 1986), although the female uncompensated wage elasticity for total labour hours seems less sensitive to the wage rate compared also to the value estimated with market labour hours (0.147). Moreover we find that the household total labour supplies are complementary, this is particularly evident in the female supply. Finally the collective framework detects similar elasticities to non-labour income: for both men and women the value is positive and rather small.

Table 10 Labor supply elasticities

	Total labor supply	
	Unrestricted Model	Collective Model
Men		
Log $\hat{w}_m$	-0.587 (0.605)	-0.356 (0.276)
log $\hat{w}_f$	0.035 (0.429)	-0.013 (0.091)
$\hat{\hat{y}}$	0.000 (0.018)	0.001 (0.002)
Women		
Log $\hat{w}_m$	-0.263 (0.099)***	-0.259 (0.099) ***
log $\hat{w}_f$	0.031 (0.097)	0.033 (0.097)
$\hat{\hat{y}}$	0.003 (0.002)	0.003 (0.002)

Note: Sample of households with both spouses working.
Asymptotic standard errors, computed by delta method, in brackets.

To sum up, the implementation of the likelihood ratio test, the derivation of the parameters required by the model, and the estimation of the labour supply elasticities are all consistent in highlighting the need for more sophisticated intra-household decision models, that take account of the individual domestic productivity as a distributional factor in the within household resource allocation process.

6. Conclusion

In this paper we developed a new technique that allows to estimate individual domestic productivity when both couple members work on the labor market.

An interesting finding is that domestic productivity is an independent determinant of labor allocation even for women who may have equalized their marginal product at home and on the market.

Our work was also devoted to testing whether a collective model of total labor supply is a better representation of intra-household decision over working/leisure time. According to our estimates, we cannot reject the collective model as above specified.

We reckon however that our analysis is subject to few limitations and that opens up future directions for research. The invalidation of the recursivity property for couples with a non working woman limits our identification technique to two earner couples only. Finally, the fact that the choice of market working hours is so heavily constrained in France might well have introduced noise in the whole exercise. In this respect repeating the estimates with survey from countries with a more flexible labour market could provide a useful sensitivity measure.

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Appendix 1

In order to write down the log likelihood function, we generalise (15) considering a non-linear model with heteroskedasticity, as it follows:

$$t_{ij} = k(\delta, X_j) + \varepsilon_j g(\delta, X_j) + \eta_j \qquad \text{with } j = 1, .., n \text{ and } i=m,f \qquad \text{(A.1).}$$

where δ is the vector of coefficients and x a vector of variables, including individual demographic characteristics X_i, and individual wage rate.

Furthermore, it follows that (A.1) can be written in a more compact form as:

$$t_{ij} = k(\delta_j, X_j) + u_j \qquad \text{with} \qquad u_i \approx N\left(0, \sqrt{\sigma_\varepsilon^2 g^2(\delta, X_i) + \sigma_\eta^2}\right)$$

and u_j being independent across observations.

Onwards, we use the following simplifications in the notation (with $j = 1, .., n$):

$$k_j = k(\delta, X_j); \qquad g_j = g(\delta, X_j); \qquad s_j^2 \approx \sigma_\varepsilon^2 g^2(\delta, X_j) + \sigma_\eta^2$$

We are now able to compute the likelihood function of a sample (t_{ij}, X_j). It comes out immediately that the likelihood of an observation is given by :

$$V_j = \frac{1}{\sqrt{2\Pi s_j}} Exp\left[-\frac{(t_{ij} - k_j)^2}{2s_j^2}\right]$$

and, for the whole sample, the log likelihood is:

$$LogL(\delta, \sigma_\varepsilon, \sigma_\eta) = -\frac{n}{2}\log(2\Pi) - \frac{1}{2}\sum_j \log\left(s_j^2\right) - \frac{1}{2}\sum_j \log\frac{(t_{ij} - k_j)^2}{s_j^2} \qquad \text{(A.2)}$$

From expression (A.2) the vector of the gradient of the likelihood derives.

Finally, the estimation of model (A.2) by ML will provide a full set of estimates, including δ the vector of coefficients and ε_j, which from total residual $u_j = \varepsilon_j g(\cdot) + \eta_j$ will be given by the following condition:

$$\hat{\varepsilon}_{ij} = E\left[\varepsilon_{ij} \middle| \varepsilon_{ij} g(\cdot) + \eta_{ij} = \hat{u}_{ij}\right]$$

knowing that $Cov[\varepsilon_i, \eta_i] = 0$.