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On the Importance of Household Production in Collective Models : Evidence from U.S. Data

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Abstract

The present paper develops a theoretical model of labor supply with domestic production. It is shown that the structural components of the model can be identified without using a distribution factor, thereby generalizing the initial results of Apps and Rees (1997) and Chiappori (1997). The theoretical model is then estimated using the ATUS data. The empirical results are compared to those obtained from a similar model without domestic production.

Key-words: collective model, market labor supply, domestic labor supply, household production, identification, ATUS

JEL-codes: D13, J21, J22

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1 Introduction

In labor supply analysis, the traditional approach describes household behavior as resulting from the decisions of a single individual, not considering the fact that most households are composed of several persons who take part in the decision process. Nevertheless, during the last two decades, several authors have aimed at explicitly introducing individualistic elements in models of household behavior. In particular, the collective model of labor supply, pioneered by Chiappori (1988, 1992), has turned out to be very attractive. In his original framework, Chiappori represents the household as a collectivity consisting of two persons, each of them being characterized by a specific utility function, that make Pareto-efficient decisions. The empirical consequences of the efficiency assumption are then analyzed in a household labor supply model, in which only total consumption and individual labor supplies are observable by the outside econometrician. Chiappori shows that, if preferences are of the egoistic type and consumption is purely private, the rule that describes how household resources are shared between spouses can be identified (up to a constant) from the sole estimation of spouses' labor supply functions. Chiappori, Fortin and Lacroix (2002) complete the preceding identification results for the case where the econometrician observes distribution factors, that is, some variables that, by definition, influence the sharing of resources within the household without affecting preferences or the budget constraint.[1]

The initial formulation of the collective model of labor supply is based on the strong hypothesis that all non-market time coincides with leisure. In other words, the possibility of time spent in home production activities is simply ignored. Apps and Rees (1996, 1997) rightly point out that, in that case, a low level of market labor supply is automatically interpreted as greater consumption of leisure, whereas it may in fact reflect the specialization of one of the members in home production. These authors conclude that the presence of homework may significantly distort welfare analysis based on Chiappori's (1992) identification results. Moreover, Donni (2008) shows that welfare analysis will be unbiased only in the case where the domestic production function is additively separable in spouses' time inputs, that is, the case where the time devoted to domestic chores by each spouse is independent of the wage rate of her/his partner. Yet this result is essentially theoretical. It says nothing on the size of the distortions, due to the omission of domestic production, in welfare analysis that are carried out with real data.

The identification results for the collective model of labor supply have, however,

[1] See Chiappori and Donni (2011) for a recent survey of the collective model literature.

been extended to allow for the existence of household production. In particular, Chiappori (1997) considers a generalization of his initial model where consumption goods can be purchased on the market or produced from a technology using spouses' time input. He then shows that, in the case of marketable domestic production, and if there is at least one distribution factor,[2] the sharing rule can be completely identified (up to a constant) from the estimation of market and domestic labor supply functions.[3] One of the very rare estimations of this model is proposed by Rapoport, Sofer and Solaz (2011) with French data.[4] These authors concentrate on a sample of couples where both spouses are working and estimate a system of total labor supply functions (defined as the sum of domestic and market labor supply functions).[5]

In the present paper, we consider the collective model of labor supply with (marketable) domestic production. Our objectives are threefold.

Firstly, we will prove a new identification result for the collective model of labor supply with marketable domestic production for the case where no distribution factor is observable. More precisely, we will show that, even in that case, the sharing rule can be retrieved up to a constant provided a complete system of domestic and market labor supply functions is estimated. This theoretical result, as simple as it may be, is original and important because finding (exogenous) distribution factors is always a difficult task for the econometrician. In addition, this new identification result will allow us to underline the close relationship between the initial model of Chiappori (1992) and its generalized version with domestic production.

Secondly, we will present estimations of the sharing rule using data from the American Time Use Survey (ATUS). Our theoretical model is basically the same as that of

[2]To be precise, the identification result of Chiappori (1997) does not rely on the existence of distribution factors. The econometrician is supposed to observe the amount of nonlabor income, respectively, for each spouse. Nevertheless, the observation of various sources of exogenous income that affect differently the sharing of resources plays exactly the same role as distribution factors. This point is emphasized by Chiappori (1997, footnote 1).

[3]The marketability (or complete market) assumption, though restrictive, is essential to guarantee the identification of the structural components of the model. Even in the unitary approach, the model of domestic production developed by Gronau (1977, 1980) and its numerous extensions (Graham and Green, 1984; Solberg and Wong, 1992) cannot avoid using this very assumption to disentangle utility functions and production functions from observed household behavior.

[4]Estimations of variations of this model are also given by Apps and Rees (1996, Australia); Aronsson, Daunfeldt and Wikstrom (2001, Sweden); Couprie (2007, United Kingdom).

[5]The theory of collective models with domestic production, up to now, does not deal with the spouses' decision to participate in the labor market. For the particular case where there is no domestic production, see Donni (2003, 2007) for the theoretical and empirical study of the decision to participate in the labor market.

Chiappori (1997). The method of estimation, however, is quite different from that of Rapoport, Sofer and Solaz (2011). The first divergence is that a complete system of market and domestic labor supply equations is estimated, and not only the total labor supply equations. This is necessary because distribution factors are not used here for identifying the structural components of the model. The second divergence is that the selection of working couples on which estimations are performed is modeled using the Heckman method. In addition, the ATUS data are particularly well adapted to our purpose, for at least two reasons: (i) the labor market is much more flexible in the US than in France so that market working time contains a lot of information on household decision process that can be exploited by the econometrician, (ii) the number of households questioned in the ATUS is considerable so that estimations can be performed on a very large, well-calibrated sample of couples.

Thirdly, we will systematically study the distortions generated by the omission of domestic production from an empirical perspective. To do so, the functional form for market labor supply we use is consistent with Chiappori's (1992) model as well as with Chiappori's (1997) model. Our results then connect the discrepancies that may exist between the structural estimates of these two models to the properties of the domestic labor supply functions.

The paper is structured as follows. In section 2, we present the collective model of labor supply with and without domestic production in the absence of distribution factors. In section 3, we present the empirical specification of our model. In section 4, we discuss the data used and the estimation method. In section 5, we report estimation results and, in section 6, we conclude.

2 The Collective Model of Labor Supply

In what follows, we will focus on a two-person household that makes decisions about consumption and leisure, and we adopt two fundamental assumptions. (i) Each household member is characterized by a specific, egoistic utility function that depends on consumption of good C^i and leisure $T - L^i$, where T denotes total time endowment and L^i denotes individual i's total labor supply (i.e., the sum of domestic and market labor supply), with $i = 1, 2$.[6] The utility is represented by a strictly quasiconcave, monotonic, and sufficiently smooth function, that is,

$$U^i(C^i, T - L^i, \mathbf{d}),$$

[6] As explained by Chiappori (1992), all the results that follow still hold in the case of caring (not paternalistic) preferences.

where $\mathbf{d}$ is a vector of socio-demographic factors that may affect individual preferences.[7] We also suppose, as a convention, that individual 1 is the "husband"and individual 2 the "wife". (ii) The outcome of the decision process is Pareto optimal, that is, at the equilibrium, it is not possible to increase the welfare of one household member without decreasing the welfare of the other household member. This configuration defines the so-called collective approach. This approach can be legitimized referring to the theory of repeated games under perfect information. Since the household is a typical example of such repeated games, it is plausible that efficient decision process could be developed by its members.

We will then consider two variations of the collective model of labor supply, namely, Chiappori (1992)'s model without domestic production and Chiappori (1997)'s model with domestic production.

2.1 The model without household production

In what follows, we shall focus on interior solutions, i.e., total labor supply, leisure and consumption are positive.[8] If there is no domestic production, total labor supply L^i coincides with market labor supply. Moreover, all the consumption of household members is purchased on the market. If taxation is ignored, and the price of consumption is normalized to one, the budget constraint is then equal to:

$$C^1 + C^2 \leq w_1 L^1 + w_2 L^2 + y,$$

where L^i denotes here individual i's market labor supply (which coincides with total labor supply), w_i are individual wage rates (exogenously determined by the market) and y is nonlabor income (or net expenditure, the two concepts being equivalent when there is no savings). Chiappori (1992) shows that, given the assumptions of efficiency and egoistic preferences, the household decision program can be reduced to a two-stage decision process. At the first stage, nonlabor income y is shared among household members according to a sharing rule where individual 1 gets $\Phi^1 = \Phi(w_1, w_2, y, \mathbf{d})$ and individual 2 gets $\Phi^2 = y - \Phi(w_1, w_2, y, \mathbf{d})$. At the second stage, each individual separately allocates his or her income to own consumption and leisure in a way that maximize his or her own utility subject to an individual budget constraint. Formally, the result is stated as follows.

[7] To simplify notation, we suppose that these factors are the same for both spouses.

[8] Therefore, we shall also ignore the non-negativity constraints in the subsequent optimization problems.

Lemma 1. *The Pareto optimal allocations* (C^i, L^i) *are solution of the following decentralized programs:*

$$\max_{\{C^i, L^i\}} U^i(C^i, T - L^i, \mathbf{d}) \tag{1}$$

subject to:

$$C^i \leq w_i L^i + \Phi^i(w_1, w_2, y, \mathbf{d}).$$

for some functions $\Phi^i(w_1, w_2, y, \mathbf{d})$, *where* $\sum_i \Phi^i(y, w_1, w_2, \mathbf{d}) = y$. *Individual market labor supply functions can be written as:*

$$L^i = F^i(w_i, \Phi^i(w_1, w_2, y, \mathbf{d}), \mathbf{d}) \tag{2}$$

for some Marshallian labor supply functions $F^i(\cdot)$.

Proof. This sharing rule interpretation derives directly from an application of the second fundamental theorem of welfare economics; see also Chiappori (1992). □

In principle, the sharing function $\Phi^i(w_1, w_2, y, \mathbf{d})$ may also depend on additional variables, distinct from socio-demographic factors, that are called "distribution factors". For instance, Chiappori, Fortin and Lacroix (2002) and Rapoport, Sofer and Solaz (2011) use the sex ratio in the surrounding population as argument of the sharing functions. The intuition is that a change in the respective number of male and female potential partners in the marriage market may modify the balance of power in the household (Becker, 1993). The existence of distribution factors may make identification easier. To be valid, however, distribution factors must be excluded from the arguments of the utility functions, which is a restrictive assumption. If this exclusion does not hold, identification of the sharing functions may well be biased. In what follows we thus decided to start from the assumption that the econometrician does *not* observe distribution factor, and to examine identification issues in this very case.

The previous lemma has two consequences. From equation (2), let us note, that individual i's wage rate has only an income effect on member j's labor supply through the individuals' share of nonlabor income. This property is restrictive and can be empirically tested for sufficiently flexible functional forms; see Chiappori (1988, 1992). In addition, the sharing functions can be generically identified up to an additive function of socio-demographic variables (that boils down to a constant when these variables are omitted from the analysis) from the estimation of the market labor supply functions. For the sake of completeness, we will now present this well-known result. First of all, to make explicit the regularity conditions that must be satisfied, we suppose that[9]

$$L_y^1 \cdot L_y^2 \neq 0, \tag{R–1}$$

and write $A = L_{w_2}^1 / L_y^1$ and $B = L_{w_1}^2 / L_y^2$, so that we can define:

$$\alpha = \frac{AB_y - B_{w_2}}{A_{w_1} + AB_y - B_{w_2} - A_y B}, \qquad \text{and} \qquad \beta = (1 - \alpha).$$

provided that

$$A_{w_1} + AB_y \neq A_y B + B_{w_2}. \tag{R–2}$$

The identification result of Chiappori (1992) is formally given below.

Proposition 2. *Under conditions (R–1) and (R–2), the individual shares are identified up to one additive function of socio-demographic factors from the estimation of market labor supply functions. In particular the partial derivatives of individual 1's share of income are given by*

$$\Phi_y^1 = \alpha, \quad \Phi_{w_2}^1 = A\alpha, \quad \text{and} \quad \Phi_{w_1}^1 = -B\beta,$$

and those of individual 2's share by

$$\Phi_y^2 = \beta, \quad \Phi_{w_2}^2 = -A\alpha, \quad \text{and} \quad \Phi_{w_1}^2 = B\beta,$$

Proof. See Chiappori (1992). □

The basic idea of this result is explained by Chiappori (1992). Changes either in nonlabor income or in the spouses ' wage rate can have only an income effect; specifically, they will affect the member's behavior only insofar as her share of nonlabor income is modified. Hence any simultaneous change in nonlabor income and spouse i's wage rate that leaves unchanged spouse j's labor supply must keep constant j's share as well. From this idea, it is possible to derive the indifference surfaces of this share in the space (w_i, y). Since both shares add up to one, the sharing functions themselves can actually be recovered up to a function of socio-demographic factors. From the knowledge of the individual budget constraints, the individual utility functions can then be recovered (up to the function at stake).

[9] In our notation, f_x stands for the derivative of function f with respect to variable x.

2.2 The model with household production

From now on we consider the collective model of labor supply with domestic production. First of all we suppose that household members share their time between leisure, market work and domestic activities. The time devoted to domestic production by individual i is denoted by t^i and the time devoted to market work by h^i, and total working time of individual i is then given by

$$L^i = t^i + h^i.$$

As preceedingly, we consider interior solutions and suppose, in particular, that spouses work in the market as well as in the household entreprise. Moreover, we follow Gronau (1977, 1980) and suppose that the domestic good can be exchanged on a competitive market at a constant price. This is the marketability assumption. In other words, total consumption of individual i can be divided between consumption purchased on the market and consumption produced within the household. The purchased quantity is denoted by x^i and the produced quantity by z^i. Hence total consumption of individual i is simply equal to[10]

$$C^i = x^i + z^i.$$

Finally, the technology of production is represented by a strictly concave and smooth function, that is,

$$z^1 + z^2 = Z(t^1, t^2, \mathbf{d}),$$

where the technology is supposed to depend on the vector of socio-demographic factors. Thanks to the marketability assumption (and the fact that spouses participate in the labor market), the spouses' decisions regarding production and consumption can be seen as sequential, that is, the household first solves its production problem and maximize household profit, and then allocates nonlabor income and the profit obtained from the first stage to consumption: each member maximizes separately her/his own welfare under her/his own budget and time constraints. This result is formally presented below.

[10]In his collective model with household production, Chiappori (1997) supposes that individual utility functions have both consumptions x_i and z_i as specific arguments. Since the price of the domestic good z_i is exogenous and constant, however, total consumption can be represented by a Hicksian aggregate good C_i. This is the approach we follow here. We proceed in such a way for two reasons. Firstly, the traditional exposition of Gronau's (1977) model and its sequels start from the same postulate that utility is a function of leisure and total consumption only. Secondly, this presentation underlines what are the most important differences between the collective model of labor supply without domestic production and its counterpart with domestic production.

Lemma 3. *The Pareto optimal allocations (t^i, C^i, L^i) are solution of the following decentralized programs:*

A. *At the first stage, the optimal allocation of time to household production is obtained by maximizing profit,*

$$\max_{\{t^1,t^2\}} \left\{Z(t^1, t^2, \mathbf{d}) - t^1 w_1 - t^2 w_2\right\} = \Pi(w_1, w_2, \mathbf{d})$$

and the solutions are domestic labor supply functions:

$$t^i = g^i(w_1, w_2, \mathbf{d}).$$

B. *At the second stage, each household member maximizes his or her utility subject to his or her budget constraint:*

$$\max_{\{C^i,L^i\}} U^i(C^i, T - L^i, \mathbf{d})$$

subject to

$$C^i = w_i L^i + \Psi^i(y, w_1, w_2, \mathbf{d})$$

for some functions $\Psi^i(y, w_1, w_2, \mathbf{d})$, where $\sum_i \Psi^i(y, w_1, w_2, \mathbf{d}) = y + \Pi(w_1, w_2, \mathbf{d})$. The solutions are the total labor supply functions:

$$L^i = F^i(w_i, \Psi^i(y, w_1, w_2, \mathbf{d}), \mathbf{d})$$

for some Marshallian labor supply functions $F^i(\cdot)$.

Proof. This results is a straightforward implication of the second theorem of welfare economics; see also Chiappori (1997). □

One important implication of this lemma is that market labor supply functions have the following structure:

$$h^i(y, w_1, w_2, \mathbf{d}) = F^i(w_i, \Psi^i(y, w_1, w_2, \mathbf{d}), \mathbf{d}) - g^i(w_1, w_2, \mathbf{d}), \tag{3}$$

where $\sum_i \Psi^i(y, w_1, w_2, \mathbf{d}) = y + \Pi(w_1, w_2, \mathbf{d})$, that is, market working time is equal to total working time minus domestic working time.

Our new theoretical result, which is exposed below, is that, *even in absence of distribution factors*, the sharing functions can be identified up to additive functions of socio-demographic variables. This result is the counterpart for the model with household production to the result of Chiappori (1992); and, in this sense, it generalizes the result of Chiappori (1997). To show this, we suppose, as previously, that

$$L_y^1 \cdot L_y^2 \neq 0, \tag{R–1$'$}$$

and define: $A = L_{w_2}^1 / L_y^1$ and $B = L_{w_1}^2 / L_y^2$. In addition, if

$$A_{w_1} + AB_y \neq A_y B + B_{w_2}, \tag{R–2$'$}$$

we define:

$$\alpha^* = \frac{AB_y - B_{w_2} - t_{w_2}^1}{A_{w_1} + AB_y - B_{w_2} - A_y B} \qquad \text{and} \qquad \beta^* = 1 - \alpha^*.$$

The identification result is then as follows.

Proposition 4. *Under conditions (R–1$'$) and (R–2$'$), the individual shares are identified up to* <u>*two*</u> *functions of socio-demographic variables (one for each individual share) from the estimation of market and domestic labor supply functions. In particular the partial derivatives of individual 1's share of income are given by*

$$\Psi_y^1 = \alpha^*, \quad \Psi_{w_2}^1 = A\alpha^*, \quad \textit{and} \quad \Psi_{w_1}^1 = -t^1 - B\beta^*,$$

and those of individual 2's share by

$$\Psi_y^2 = \beta^*, \quad \Psi_{w_2}^2 = -t^2 - A\alpha^*, \quad \textit{and} \quad \Psi_{w_1}^2 = B\beta^*.$$

Proof. See Appendix. □

The intuition is basically the same as that of the previous identification result, noting that the profit function entering total labor supply functions can be recovered, using the Hotelling lemma, from the integration of domestic labor supply functions. However, the number of unidentified functions is equal to two here (instead of one in the preceding proposition). Indeed the profit function that enters the budget constraint is itself defined up to a function of socio-demographic factors. Once these functions are picked up, the individual preferences can be uniquely recovered.

Note also that identification from the proposition above requires the estimation of both market and domestic labor supply functions, *separately*. Indeed, the functions α^* and β^* are constructed with the *derivatives* of domestic labor supply functions. By contrast, the sharing functions in the model with distribution factors can be retrieved, as pointed out by Rapoport, Sofer and Solaz (2011), from the estimation of the sole total labor supply functions, i.e., the sum of market and domestic labor supply functions, because the formulae that define the structural components of the model in this case depends only on the *quantity* of domestic labor supply. In other words, even if the observation of time devoted to domestic chores is necessary in both cases, identification necessitates the estimation of four equations in the case without distribution factors, instead of two equations in the other case.

2.3 Robustness of the results: incomplete markets and joint consumption

One of the key assumptions here is that home time produces a good that has a perfect (or close at least) substitute sold on the market at a constant price. In that case, the price of the domestic good is exogenously fixed by the market and the household members devote their time to domestic production up to the point at which marginal productivity equals the ratio of the wage to the price of the good. This assumption does not pose any important difficulty for farm households with a significant activity in agricultural production. In the agricultural economics literature, the idea that households are price-takers for every good (including domestic production) is generally accepted by economists. One reservation, however, is that the buying price of the domestic good may well be larger than the selling price because of taxes and transaction costs. Formally, let us suppose that the price of the domestic good at the margin is equal to one if the household is a net seller and to $p > 1$ if the household is a net buyer. Hence, for some subset of exogenous variables such that there is no transaction on the market, the price of the domestic good is endogenously determined and comprised between one and the buying price p. Technically, the framework with complete market presented here is not valid in that very case. However, the subset of exogenous variables in question may often be neglected in empirical applications.

The area of application of the present model is certainly not restricted to the study of agricultural production, though. The marketability assumption can also be used to describe the behavior of urban households. For instance, the labor supply model developed by Gronau (1977) is based on the idea that the same goods and services (such as cleaning or catering) can be produced at home or bought on outside markets at a given price. This is exactly our claim here. Of course, the goods produced within the household are, in general, not perfectly substitutable with those traded on the market. If so, the price of the domestic good is endogenously determined within the household and enters, as an additional argument, the total labor supply functions and the profit function. Even in that case, however, the marketability assumption can still be seen as a useful approximation because it makes possible to derive strong identification results. This approximation is well-founded if the marginal rate of substitution between the goods produced within the household and the goods purchased on the market is almost constant.

The assumption that household consumption is purely private, on the other hand, is restrictive as well, and deserves to be examined. If consumption is public, the price of the consumption good will be specific to individuals living in the household and/or endogenously determined. Our claim here is that the collective model of labor supply with private consumption is a good approximation of a more general model provided that the shadow price of consumption is not excessively flexible. To take an example, let us suppose that the consumption good has a public and a private element. The fraction of the good that is publicly consumed by both spouses is equal to γ, and the fraction that is privately consumed is equal to $1-\gamma$. If so, one unit of the (purchased or produced) good will generate a total consumption for both spouses equal to $1+\gamma$ and the shadow price of consumption will be equal to $1/(1+\gamma)$. This shadow price enters, as an additional argument, the total labor supply functions and the profit function (without precluding the marketability assumption, though). If γ is constant, however, the shadow price is constant and the framework with private consumption presented here is still valid.

3 Functional Form and Stochastic Specification

3.1 The reduced-form model

Our strategy is to choose a functional form for the reduced-form model and to derive the structural parameters from it. To evaluate the role of domestic production, the reduced-form model must be consistent with both Chiappori's (1992) model and Chiappori's (1997) model. As a point of departure, we consider a linear specification for the domestic labor supply functions,

$$t^1 = A_0(\mathbf{d}) + A_1 w_1 + A_2 w_2 + u_1, \tag{4}$$
$$t^2 = B_0(\mathbf{d}) + B_1 w_2 + B_2 w_1 + u_2, \tag{5}$$

where $A_0(\mathbf{d}), B_0(\mathbf{d})$ are linear functions of the socio-demographic factors, $A_1, \ldots, B_2$ are parameters and u_1 and u_2 are stochastic terms. For the market labor supply functions, we consider a quadratic specification,

$$h^1 = a_0(\mathbf{d}) + a_1 w_1 + a_2 w_2 + a_3 w_1^2 + a_4 w_2^2 + a_5 w_1 w_2 + a_6 y + u_3, \tag{6}$$
$$h^2 = b_0(\mathbf{d}) + b_1 w_1 + b_2 w_2 + b_3 w_1^2 + b_4 w_2^2 + b_5 w_1 w_2 + b_6 y + u_4, \tag{7}$$

where $a_0(\mathbf{d}), b_0(\mathbf{d})$ are linear functions of the socio-demographic factors, $a_1, \ldots, b_6$ are parameters and u_3 and u_4 are stochastic terms. This specification is sufficiently flexible for the present purpose.[11] For the sake of our discussion, we suppose that stochastic terms represent unobservable heterogeneity in preferences, in the sharing function and in the profit function. In the empirical application, stochastic terms will also represent optimization and measurement errors.

In what follows, we will consider two cases, whether the econometrician accounts for domestic production or not, and two different structural models. In the former case, the system of four equations (4)–(7) is estimated and the sharing functions are identified using all the information about spouses' market and domestic labor behavior. In the latter case, the system of only two equations (6)–(7) is estimated. The uniqueness of the parameters of the sharing functions (except for some functions of socio-demographic factors) is then guaranteed from propositions 2 and 4. In other words the structural parameters of the sharing functions are defined as a combination of the parameters of the reduced form of labor supply equations.

3.2 Structural-Form Model 1: The Model without Domestic Production

If there is no domestic production, we can show that the unique specification for the husband's share of income compatible with (6)–(7) is

$$\Phi^1(w_1, w_2, y, \mathbf{d}) = \kappa_0(\mathbf{d}) + \kappa_1 w_1 + \kappa_2 w_2 + \kappa_3 w_1^2 + \kappa_4 w_2^2 + \kappa_5 w_1 w_2 + \kappa_6 y,$$

and for the wife's share of income by

$$\Phi^2(w_1, w_2, y, \mathbf{d}) = y - \Phi^1(w_1, w_2, y, \mathbf{d}),$$

where $\kappa_0(\mathbf{d})$ is some unidentified (possibly stochastic) function while[12]

$$\kappa_1 = a_5 b_1 / \left(a_6 b_5 - a_5 b_6\right), \tag{8a}$$

$$\kappa_2 = a_2 b_5 / \left(a_6 b_5 - a_5 b_6\right), \tag{8b}$$

$$\kappa_3 = a_5 b_3 / \left(a_6 b_5 - a_5 b_6\right), \tag{8c}$$

$$\kappa_4 = a_4 b_5 / \left(a_6 b_5 - a_5 b_6\right), \tag{8d}$$

$$\kappa_5 = a_5 b_5 / \left(a_6 b_5 - a_5 b_6\right), \tag{8e}$$

$$\kappa_6 = a_6 b_5 / \left(a_6 b_5 - a_5 b_6\right), \tag{8f}$$

[11] For the reduced-form domestic labor supply functions, a quadratic specification is not compatible with the quadratic specification of the reduced-form market labor supply functions.

[12] We do not explicitly derive the structural parameters here, which would be fastidious. The reader can easily check that incorporating (8) and (11) in (9) and (10) gives (6) and (7). Of course, the same remark applies for the other model.

provided that $a_6 b_5 \neq a_5 b_6$ (a regularity condition). In addition, the structural form of the spouses' total labor supply functions are given by

$$L^1 = \alpha_0(\mathbf{d}) + \alpha_1 w_1 + \alpha_2 w_1^2 + \alpha_3 \Phi^1(w_1, w_2, y, \mathbf{d}), \tag{9}$$
$$L^2 = \beta_0(\mathbf{d}) + \beta_1 w_2 + \beta_2 w_2^2 + \beta_3 \Phi^2(w_1, w_2, y, \mathbf{d}), \tag{10}$$

where, as previously, $\alpha_0(\mathbf{d})$ and $\beta_0(\mathbf{d})$ are some unidentified functions,

$$\alpha_0(\mathbf{d}) = a_0(\mathbf{d}) + u_3 - (a_6 - a_5 b_6/b_5)\,\kappa_0(\mathbf{d}), \tag{11a}$$
$$\beta_0(\mathbf{d}) = b_0(\mathbf{d}) + u_4 + (b_6 - b_5 a_6/a_5)\,\kappa_0(\mathbf{d}), \tag{11b}$$

while

$$\alpha_1 = a_1 - a_5 b_1/b_5, \tag{11c}$$
$$\beta_1 = b_2 - b_5 a_2/a_5, \tag{11d}$$
$$\alpha_2 = a_3 - a_5 b_3/b_5, \tag{11e}$$
$$\beta_2 = b_4 - b_5 a_4/a_5, \tag{11f}$$
$$\alpha_3 = a_6 - a_5 b_6/b_5, \tag{11g}$$
$$\beta_3 = b_6 - b_5 a_6/a_5. \tag{11h}$$

Once $\kappa_0(\mathbf{d})$ is fixed to some value (e.g., it is identically equal to zero), the values of $\alpha_0(\mathbf{d})$ and $\beta_0(\mathbf{d})$ are uniquely defined. Note that the structural model does not generate over-identifying restrictions. Nevertheless, the model can be empirically tested because of the Slutsky Positivity condition that must be satisfied by labor supply functions. This condition is globally satisfied if $\alpha_1, \beta_1 > 0$, $\alpha_2, \beta_2 > 0$ and $\alpha_2, \beta_3 < 0$. The normality of leisure can also be tested separately.

The structural model of market labor supply is flexible in the sense that it is consistent with both forward and backward bending supply curves. In addition, the utility functions that are behind these market labor supply functions have a closed form which is formally derived by Hausman and Ruud (1986) and Kapteyn, Kooreman, and van Soest (1990). Instead of presenting these functions that are rather intricate, we would like to underline that, using the Roy's identity, the effect of wage rates and nonlabor income on husband's utility can be written as:

$$\Delta U_1 = \lambda_1 \times (L_1 + \kappa_1 + 2\kappa_3 w_1 + \kappa_5 w_2) \times \Delta w_1, \tag{12a}$$
$$\Delta U_1 = \lambda_1 \times (\kappa_2 + 2\kappa_4 w_2 + \kappa_5 w_1) \times \Delta w_2, \tag{12b}$$
$$\Delta U_1 = \lambda_1 \times \kappa_6 \times \Delta y, \tag{12c}$$

where λ_1 is an arbitrary scalar representing the marginal utility of money for the husband (Donni, 2008). Therefore, the knowledge of shares of income allows carrying out welfare analysis at the individual level. Needless to say, similar expressions could be derived for the wife's utility.

3.3 Structural-Form Model 2: The Model with Domestic Production

If there is domestic production, we can show, as a consequence of Hotelling lemma, that the unique profit function compatible with domestic labor supply functions is

$$\Pi(w_1, w_2, \mathbf{d}) = \pi_0^*(\mathbf{d}) + \pi_1^* w_1 + \pi_2^* w_2 + \pi_3^* w_1^2 + \pi_4^* w_2^2 + \pi_5^* w_1 w_2,$$

where $\pi_0^*(\mathbf{d})$ is some unidentified function while

$$\pi_1^* = -A_0(\mathbf{d}) - u_1, \quad (13a)$$
$$\pi_2^* = -B_0(\mathbf{d}) - u_2, \quad (13b)$$
$$\pi_3^* = -A_1/2, \quad (13c)$$
$$\pi_4^* = -B_1/2, \quad (13d)$$
$$\pi_5^* = -A_2 = -B_2 = -C, \quad (13e)$$

where the last equality is a testable restriction. This profit function is locally regular (that is, non-increasing and convex in the prices of production factors) if $\pi_3^* < 0$, $\pi_4^* < 0$ and $\pi_3^*\pi_4^* - (\pi_5^*)^2 > 0$ and if its derivatives with respect to wage rates w_1 and w_2 are non-positive. However, the regularity domain will be very large if domestic working time is insensitive to changes in wage rates. As we shall see, this is the case in our empirical application.

The unique specification for the husband's share of income compatible with (4)–(7) is given by

$$\Psi^1(w_1, w_2, y, \mathbf{d}) = \kappa_0^*(\mathbf{d}) + \kappa_1^* w_1 + \kappa_2^* w_2 + \kappa_3^* w_1^2 + \kappa_4^* w_2^2 + \kappa_5^* w_1 w_2 + \kappa_6^* y,$$

and for the wife's share of income by

$$\Psi^2(w_1, w_2, y, \mathbf{d}) = y + \Pi(w_1, w_2, \mathbf{d}) - \Psi^1(w_1, w_2, y, \mathbf{d}).$$

where $\kappa_0^*(\mathbf{d})$ is some unidentified function while

$$\kappa_1^* = \kappa_1 \left(1 + \frac{a_5 + a_6 b_1 + a_6 C}{a_5 b_1} C\right) - A_0(\mathbf{d}) - u_1, \tag{14a}$$

$$\kappa_2^* = \kappa_2 \left(1 + \frac{b_5 + a_2 b_6 + b_6 C}{a_2 b_5} C\right), \tag{14b}$$

$$\kappa_3^* = \kappa_3 \left(1 + \frac{a_6}{a_5} C\right) - \frac{A_1}{2}, \tag{14c}$$

$$\kappa_4^* = \kappa_4 \left(1 + \frac{b_6}{b_5} C\right), \tag{14d}$$

$$\kappa_5^* = \kappa_5 \left(1 + \frac{b_6}{b_5} C\right), \tag{14e}$$

$$\kappa_6^* = \kappa_6 \left(1 + \frac{b_6}{b_5} C\right). \tag{14f}$$

These relations put the emphasis on the differences between the parameters of the sharing functions derived from the two structural models. In particular, let us note that, if $C = 0$, that is, if the cross-effect of wage rates on domestic labor supply is equal to zero, the effect of nonlabor income and the cross-effect of wage rates on individual shares are the same in both models (that is, only the own-effect of wage rates on individual shares are different). Finally, the spouses' total labor supply functions are given by:

$$L^1 = \alpha_0^*(\mathbf{d}) + \alpha_1^* w_1 + \alpha_2^* w_1^2 + \alpha_3^* \Psi^1(w_1, w_2, y, \mathbf{d}), \tag{15}$$

$$L^2 = \beta_0^*(\mathbf{d}) + \beta_1^* w_2 + \beta_2^* w_2^2 + \beta_3^* \Psi^2(w_1, w_2, y, \mathbf{d}), \tag{16}$$

where $\alpha_0^*(\mathbf{d})$ and $\beta_0^*(\mathbf{d})$ are some unidentified functions,

$$\alpha_0^*(\mathbf{d}) = a_0(\mathbf{d}) + u_3 - \frac{a_6 b_5 - a_5 b_6}{b_5 + C b_6} \kappa_0^*(\mathbf{d}) + \left(A_0(\mathbf{d}) + u_1\right), \tag{17a}$$

$$\beta_0^*(\mathbf{d}) = b_0(\mathbf{d}) + u_4 - \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6} \left(\pi_0^*(\mathbf{d}) - \kappa_0^*(\mathbf{d})\right) + \left(B_0(\mathbf{d}) + u_2\right), \tag{17b}$$

while

$$\alpha_1^* = a_1 - \frac{a_5 b_6 - a_6 b_5}{b_5 + C b_6}(A_0(\mathbf{d}) + u_1) - \frac{a_5 + C a_6}{b_5 + C b_6}(b_1 + C) + A_1, \quad (17c)$$

$$\beta_1^* = b_2 + \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}(B_0(\mathbf{d}) + u_2) - \frac{b_5 + C b_6}{a_5 + C a_6}(a_2 + C) + B_1, \quad (17d)$$

$$\alpha_2^* = a_3 - \frac{a_5 b_6 - a_6 b_5}{b_5 + C b_6}\frac{A_1}{2} - \frac{a_5 + C a_6}{b_5 + C b_6} b_3, \quad (17e)$$

$$\beta_2^* = b_4 + \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}\frac{B_1}{2} - \frac{b_5 + C b_6}{a_5 + C a_6} a_4, \quad (17f)$$

$$\alpha_3^* = \frac{a_6 b_5 - a_5 b_6}{b_5 + C b_6}, \quad (17g)$$

$$\beta_3^* = \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}. \quad (17h)$$

Similarly to what is obtained for the previous structural-form, the marginal effect of wage rates and nonlabor income on the husband's welfare is given by:

$$\Delta U_1^* = \lambda_1^* \times (L_1 + \kappa_1^* + 2\kappa_3^* w_1 + \kappa_5^* w_2) \times \Delta w_1, \quad (18a)$$

$$\Delta U_1^* = \lambda_1^* \times (\kappa_2^* + 2\kappa_4^* w_2 + \kappa_5^* w_1) \times \Delta w_2, \quad (18b)$$

$$\Delta U_1^* = \lambda_1^* \times \kappa_6^* \times \Delta y. \quad (18c)$$

Substituting the values obtained for $\kappa_1^*, \ldots, \kappa_6^*$, and assuming that $C = 0$, it is easy to show that

$$\frac{\Delta U_1^* / \Delta w_1}{\lambda_1^*} = \frac{\Delta U_1 / \Delta w_1}{\lambda_1},$$

$$\frac{\Delta U_1^* / \Delta w_2}{\lambda_1^*} = \frac{\Delta U_1 / \Delta w_2}{\lambda_1},$$

$$\frac{\Delta U_1^* / \Delta y}{\lambda_1^*} = \frac{\Delta U_1 / \Delta y}{\lambda_1}.$$

In words, both structural models give the same measurement of welfare variations provided that the cross-wage term of domestic labor supply equations is equal to zero. A similar conclusion is drawn by Donni (2008) and Donni and Moreau (2007) in a collective model with distribution factors (the latter authors also present the intuition behind this result).

4 Data and Estimation Method

4.1 Data

The main data used in this work are the American Time Use Survey (ATUS) for the year 2003 to 2006. The data collection was sponsored by the U.S. Bureau of

Labor Statistics (BLS), developed by the U.S. Bureau of the Census. The ATUS sample is chosen from the households that completed their eighth (final) interview for the Current Population Survey (CPS), the U.S. labor force survey, and was designed to provide nationally representative estimates of time that Americans spend in various activities. The ATUS collects data – through telephone interviews – about daily activities from all segments of the population of age 15 and over, including persons who are employed, unemployed, or not in the labor force (such as students or retirees), for both weekdays and weekends. Since the ATUS uses the CPS as a sampling frame, it also contains the same demographic information as the CPS.

The original sample includes 116,223 households. We selected a subsample of married couples without children. The presence of children, indeed, is not consistent with our theoretical model.[13] We also restrict the sample to couples in which both members have a job and are between 25 and 60 years old. This selection, the exclusion of missing or incomplete information and the merge with other data set leave us a sample of 4443 households.

In the ATUS-CPS data set, we have information on the labor market state of both household members, such as hours worked per week and weekly earning. Consequently, market wage is determined as the ratio between weekly labor income and hours worked per week. In Table 1, descriptive statistics of the sample are reported. We note that mean weekly working hours for male are about 44, whereas they are 39 for females. The male hourly wage is about $21 per hour, whereas the wage rate of females is about $17 per hour. As regards household production, the ATUS gives a detailed account of the respondent's activities, starting at 4 a.m. the previous day and ending at 4 a.m. on the interview day. For each activity reported, the interviewer asks how long the activity lasted. The definition of domestic work we use includes household activities like housework (interior cleaning, laundry, and so on), food and drink preparation, and interior and exterior maintenance. Because the ATUS collects information on household activities for only one person, randomly chosen, from the family, we know domestic labor supply for only 1413 women and 1230 men. For 1800 households, only the CPS questionary was completed: in that case, we do not know domestic labor supply neither for the husband nor for the wife. In Table 1, our data reveals that mean weekly domestic working time for male is about 7 hours, whereas it is 13 hours for working women. Finally, for each household member we know the age, the level of schooling, the ethnicity (dummy variable: Hispanic or not), the race (dummy variable: non-white or white). In the estimations,

[13] The selection of childless couples is usual in estimation of collective models (Fortin and Lacroix, 1997, and Blundell, Chiappori, Magnac, and Meghir, 2007, for instance).

Table 1: Descriptive Statistics of the Sample

Variable	Mean	St.Dev.
Man's weekly market working hours	43,733	8,463
Woman's weekly market working hours	39,327	9,086
Man's weekly domestic working hours	7,427	12,624
Woman's weekly domestic working hours	13,025	15,106
Man's market wage	20,911	11,160
Woman's market wage	17,026	9,405
Man's age	45,561	10,130
Woman's age	44,077	10,077
Man's education	13,512	1,680
Woman's education	13,569	1,665
Man's white race (dummy variable)	0,793	0,405
Woman's white race (dummy variable)	0,791	0,407
Man's hispanic origin (dummy variable)	0,104	0,305
Woman's hispanic origin (dummy variable)	0,097	0,296
Weekly net expenditure	-992,257	442,474
Region2: Midwest (dummy variable)	0,257	0,437
Region3: South (dummy variable)	0,372	0,483
Region4: West (dummy variable)	0,187	0,390
Week-end (dummy variable)	0,302	0,459

we also use information regarding the region (dummy variable: Midwest, South, West; reference is Northeast).

As pointed out by Blundell and McCurdy (1999), market hours must be expressed as a function of net expenditure, and not nonlabor income as it is sometimes made, for the empirical results to be easily interpretable. The availability of information on the family net expenditure was obtained by the imputation of this value from the U.S. Consumer Expenditure Survey (CES), for the year 2003 to the first quarter of 2006. In principle, the imputation may lead to distorted results if the surveyed populations or the questionnaires are different. However, the CES and the ATUS are both collected by the Bureau of Labor Statistics for the same population, and the two data sets are a priori comparable. From the CES, we thus selected a subsample of 683 married, childless couples in which both members have a job. For the households in this subsamble, we computed the variable "net expenditure" as total expenditure on non-durable goods minus spouses' labor earnings.[14] The variables used for the imputation of net expenditure include a second order polynomial in husband's age and education, the dummy variables for husband's race and ethnicity, a second order polynomial in wife's age and education, the dummy variables for wife's race and ethnicity, the three dummy variables for the region of residence, a dummy variable for housing tenure, the unemployment rate by state and by year, household nonlabor income (rent, social security, public assistance, alimony, interest and dividends, cash scholarships, fellowships, etc.). The last three variables are excluded from labor supply equations and are only used for identification.

4.2 Estimation Method

In what follows, we consider the estimation of the complete system, (4)–(7), of reduced-form market and domestic labor supply equations.[15] The households are indexed by $i = 1, 2, ..., N$ where N is the total number of observations. The observations do not contain complete information on spouses' time allocation. Indeed, as explained in section 4.1, only one person in the family (at most) is questioned about her/his domestic time use. Hence, out of the N observations we use in this study, we first have $N_1 < N$ observations for which male domestic labor time is reported but not female domestic labor time, we then have $N_2 < N$ observations for which female domestic labor time is reported and not male labor time, and we finally have $N_3 < N$ observations with only market labor time. The observations are ranked in this order. Furthermore, given that we concentrate our analysis of labor supply upon the subsample of households in the workforce – the situation for which our theory is suitable –, we face a sample selection problem.[16] The problem surfaces primarily for women, given that the participation rate of married woman is about 63%. Thus, we use the Heckit method (Heckman, 1976) to correct for the sample selection bias generated by the exclusion of nonworking women. Let us represent compactly the system of reduced-form market and domestic labor supply equations,

[14] The durable goods are implicitly supposed separable from the non-durables ones. The "net expenditure" variable is generally negative in the sample as labor earnings are larger than what is spent on the sole durable goods.

[15] The system (6)–(7) can be seen as a particular case of the complete system and its estimation is not discussed here.

[16] For a significant proportion of households in the sample, the observed hours for domestic labor supply are equal to zero. These observations are not discarded because these zeros are supposed to be due to measurement errors (by opposition to an optimal decision). This is a reasonable approximation as, in the ATUS, time use is reported during a single day for each individual.

including inverse Mills ratio, as the following system of four linear equations:

$$y_{i,s} = \mathbf{x}'_{i,s}\boldsymbol{\beta}_s + \sigma_s\lambda_{i,s} + u_{i,s} \qquad \text{with } s = 1, \ldots, 4 \text{ and } i = 1, \ldots, N,$$

where $y_{i,s}$ represents the explained variable s for observation i, that is, the time devoted to market or domestic activities by the husband or the wife, $y_1 = t_1$, $y_2 = t_2$, $y_3 = h_1$, and $y_4 = h_2$, $\mathbf{x}_{i,s}$ is the vector of explanatory variables, $\lambda_{i,s}$ the inverse Mills ratio, and $\boldsymbol{\beta}_s$ and σ_s the corresponding (vector of) parameters. For the domestic labor supply equations, the vector of explanatory variables $\mathbf{x}_{i,s}$ includes, in addition to wage rates, the age and the squared age of the corresponding person, the dummy variable for her/his race and her/his ethnicity, her/his education, the three dummy variables for the region of residence and a dummy for weekend days. For the market labor supply equations, the vector of explanatory variables $\mathbf{x}_{i,s}$ includes, in addition to wage rates and net expenditure, the same variables as for the domestic labor supply functions except the dummy for weekend days.

The stochastic terms on the right-hand side of these equations are supposed to be homoskedastic, uncorrelated across households but correlated across the different time uses within households. Hence the system of reduced-form equations is seemingly unrelated according to Zellner's terminology and estimated by the SUR method (Zellner, 1962).[17]

In the first stage of the estimation process, a selection equation for women's labor force participation is estimated using a Probit model and, from these estimates, the Inverse Mills ratio $\hat{\lambda}_{i,s}$ is computed. Explanatory variables include here a second order polynomial in husband's age and education, a product between husband's age and education, the dummy variables for husband's race and ethnicity, a second order polynomial in wife's age and education, a product between wife's age and education, the dummy variable for wife's race and ethnicity, the three dummy variables for the region of residence, the unemployment rate by state and by year, and household net expenditure as defined in section 4.1.

In the second stage of the estimation process, the $y_{i,s}$'s are regressed on $\mathbf{x}_{i,s}$ and $\hat{\lambda}_{i,s}$

[17] We have some reasons to believe that wage rates may be endogenous (because, in particular, of the way of constructing them (Borjas, 1980)). Excluding education from market labor supply equations and using it as an instrument for wage rates, we have also estimated the model by 3SLS (Zellner and Theil, 1962). It turned out that the results were not satisfactory, and they are not reported here. It is possible that education is not a sufficiently strong instrument in the present context. Having said that, we must keep in mind that endogeneity may bias downward the effect of wage rates on market hours in our estimations by the SUR method.

using the OLS method to obtain estimates $\hat{\boldsymbol{\beta}}_s$ and $\hat{\sigma}_s$, and then compute

$$\hat{\omega}_{st} = \frac{\sum_{i=a_{st}}^{b_{st}} \hat{u}_{i,s}\hat{u}_{i,t}}{n_{st}} \text{ for } s, t = 1, \ldots, 4,$$

where $\hat{u}_{i,s}$ is the residual calculated using OLS estimates, namely,

$$\hat{u}_{i,s} = y_{i,s} - \mathbf{x}'_{i,s}\hat{\boldsymbol{\beta}}_s - \hat{\sigma}_s\hat{\lambda}_{i,s},$$

and n_{st} is the number of observations i such that variables s and t are both observed, a_{st} and b_{st} are the upper and lower bounds of the indexes.[18] With the usual staking of observations, each reduced-form equation can be written as:

$$\mathbf{y}_s = \mathbf{X}_s\boldsymbol{\beta}_s + \sigma_s\hat{\boldsymbol{\lambda}}_s + \mathbf{u}_s,$$

where $\mathbf{y}_s$ is the vector of explained variables, $\mathbf{X}_s$ is is the matrix of fitted explanatory variables, $\boldsymbol{\lambda}_s$ is the vector of inverse Mills ratio, and $\mathbf{u}_s$ is the vector of stochastic terms. The dimension of $\mathbf{y}_s$ is N_1 for $s = 1$, N_2 for $s = 2$, and N for $s = 3$ or $s = 4$. In matrix notation, if there is no constraint on the parameters (that is, the symmetry of domestic labor supply equations is not imposed) so that the matrix $\mathbf{Z}$ below is block diagonal, the system of reduced-form equations can be written as:

$$\begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \mathbf{y}_3 \\ \mathbf{y}_4 \end{pmatrix} = \begin{pmatrix} \mathbf{Z}_1 & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{Z}_2 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{Z}_3 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{Z}_4 \end{pmatrix} \begin{pmatrix} \boldsymbol{\theta}_1 \\ \boldsymbol{\theta}_2 \\ \boldsymbol{\theta}_3 \\ \boldsymbol{\theta}_4 \end{pmatrix} + \begin{pmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \mathbf{u}_3 \\ \mathbf{u}_4 \end{pmatrix}$$

or

$$\mathbf{y} = \hat{\mathbf{Z}}\boldsymbol{\theta} + \mathbf{u}$$

where $\mathbf{Z}_s = [\mathbf{X}_s \vdots \hat{\boldsymbol{\lambda}}_s]$ and $\boldsymbol{\theta}'_s = [\boldsymbol{\beta}'_s \vdots \sigma_s]$. The estimated covariance matrix of the

[18] Precisely, $n_{st} = N_1$ and $(a_{st}, b_{st}) = (1, N_1)$ if ($s = 1$ and $t \neq 2$) or ($s \neq 2$ and $t = 1$), $n_{st} = N_2$ and $(a_{st}, b_{st}) = (N_1 + 1, N_2)$ if ($s = 2$ and $t \neq 1$) or ($s \neq 1$ and $t = 2$), $n_{st} = N_1 + N_2 + N_3 = N$ and $(a_{st}, b_{st}) = (1, N)$ if ($s = 3$ and $t = 4$) or ($s = 4$ or $t = 3$), and $n_{st} = 0$ if ($s = 1$ and $t = 2$) or ($s = 2$ and $t = 1$) so that $\hat{\omega}_{12}$ cannot be computed. Note that there exist various techniques to compute the matrix of variance in SUR estimations with unequal number of observations. See Schmidt (1977), Baltagi, Garvin, and Kerman (1989), and Hwang and Schulman (1996). Overall, the gains in efficiency are not important in using a more sophisticated technique.

vector $\mathbf{u}$ has the particular form that follows:

$$\hat{\mathbf{\Omega}} = \begin{pmatrix} \hat{\omega}_{11}\mathbf{I}_{N_1} & 0 & \hat{\omega}_{13}\mathbf{I}_{N_1} & 0 & 0 & \hat{\omega}_{14}\mathbf{I}_{N_1} & 0 & 0 \\ 0 & \hat{\omega}_{22}\mathbf{I}_{N_2} & 0 & \hat{\omega}_{23}\mathbf{I}_{N_2} & 0 & 0 & \hat{\omega}_{24}\mathbf{I}_{N_2} & 0 \\ \hat{\omega}_{31}\mathbf{I}_{N_1} & 0 & \hat{\omega}_{33}\mathbf{I}_{N_1} & 0 & 0 & \hat{\omega}_{34}\mathbf{I}_{N_1} & 0 & 0 \\ 0 & \hat{\omega}_{32}\mathbf{I}_{N_2} & 0 & \hat{\omega}_{33}\mathbf{I}_{N_2} & 0 & 0 & \hat{\omega}_{34}\mathbf{I}_{N_2} & 0 \\ 0 & 0 & 0 & 0 & \hat{\omega}_{33}\mathbf{I}_{N_3} & 0 & 0 & \hat{\omega}_{34}\mathbf{I}_{N_3} \\ \hat{\omega}_{41}\mathbf{I}_{N_1} & 0 & \hat{\omega}_{43}\mathbf{I}_{N_1} & 0 & 0 & \hat{\omega}_{44}\mathbf{I}_{N_1} & 0 & 0 \\ 0 & \hat{\omega}_{42}\mathbf{I}_{N_2} & 0 & \hat{\omega}_{43}\mathbf{I}_{N_2} & 0 & 0 & \hat{\omega}_{44}\mathbf{I}_{N_2} & 0 \\ 0 & 0 & 0 & 0 & \hat{\omega}_{43}\mathbf{I}_{N_3} & 0 & 0 & \hat{\omega}_{44}\mathbf{I}_{N_3} \end{pmatrix}.$$

which is independent of $\hat{\omega}_{12}$. This is the consequence of the fact that spouses' domestic labor supplies are not simultaneously observed for a same household. The SUR estimator is given by

$$\hat{\boldsymbol{\theta}}_{\text{SUR}} = (\mathbf{Z}'\hat{\Omega}^{-1}\mathbf{Z})^{-1}\mathbf{Z}'\hat{\Omega}^{-1}\mathbf{y}.$$

The estimation procedure is the same when the constraint of symmetry is imposed except that the matrix $\mathbf{Z}$ is not block diagonal.

One final remark concerns the selection issue. In principle, identification is based on the existence of at least one variable which appears with a non-zero coefficient in the selection equation but does not appear in the equation of interest. If the decision of not working is voluntary (i.e., resulting from the maximization of a utility function), then these variables generally do not exist for market labor supply equations. For instance, indicators of the tension on the labor market (such as unemployment rates) can be used for identifying purpose only if we suppose that nonworking wives are, for the most part, constrained by the demand side. This is not a satisfactory assumption. The alternative possibility is to pose a specific assumption on the distribution of the random terms $\mathbf{u}$. For instance, the distribution may be supposed to be normal or, more generally, to be symmetric (Powell, 1986). We do not exploit excluded instruments and thus use one of these distribution assumptions to identify the parameters in presence of the selection issue. Because of the fragility of these assumptions, however, we also estimate the model imposing $\sigma_s = 0$ for $s = 1, \ldots, 4$.

5 Estimation Results and Discussion

5.1 The reduced-form models

The estimation results for the reduced-form labor supply equations, (4)-(7), obtained by the SUR method are presented in Table 2. The estimated parameters and their standard errors are reported for the two-equation system (model without domestic production) and the four-equation system (model with domestic production), with and witout accounting for sample selection. Like it can be easily seen, the estimation results whatever the model we consider are very similar.[19] In general, standard errors are moderately smaller, in particular for socio-demographic variables, when the inverse Mills ratio is omitted from labor supply equations, but the results are not really altered.

Regarding the market labor supply equations, net expenditure has a significant impact for the husband. The parameters related to wage rates are quite precisely estimated, especially in the wife's equations where most of them are significant. Using the model with domestic production accounting for sample selection, for instance, the marginal effect of the wife's (resp. husband's) wage rate on her (resp. his) market time, computed at the average point of the sample (not exhibited in the tables), is equal to 0.153 (resp. -0.040) with a standard error of 0.023 (resp. 0.017), while the direct elasticity of wife's (resp. husband's) market labor supply is thus equal to 0.066 (resp. -0.019).[20] The estimates are actually conformed to what is generally obtained in the empirical literature based on U.S. data (Devereux, 2003, 2004; Pencavel, 1998, 2002, 2006, for instance). In particular, the fact that an increase in the husband's wage rate has a negative impact on his market hours, is not uncommon.[21] Regarding socio-demographic variables, note that the non-white and Hispanic dummies have a negative effect for men.

For the domestic labor supply equations, an increase in wife's wage rate has a negative, significant impact on her domestic hours, while an increase in husband's wage rate has virtually no impact on his domestic hours. The direct elasticity of wife's domestic labor supply, computed at the average point of the sample, is equal to -0.112. The cross effect of spouses' wage rate is positive, and significantly different from zero, indicating that time inputs are substitute in the production process. The hypothesis of a (very moderate) substitutability between time inputs is supported by several empirical studies with U.S. data (Gronau, 1977, 1980; Graham and Green,

[19] Technically, empirical results for reduced-form market labor supply equations would be the same for the model with domestic production and the model without domestic production if $\hat{\omega}_{13} = \hat{\omega}_{14} = \hat{\omega}_{23} = \hat{\omega}_{24} = 0$.

[20] The standard errors of the marginal effects at stake here (and of the structural parameters computed below) are calculated using the Delta method. That is, given the marginal effects $\boldsymbol{\gamma}$ (say) expressed as a function of the reduced-form parameters $\boldsymbol{\beta}$ (say), namely, $\boldsymbol{\gamma} = \mathbf{f}(\boldsymbol{\beta})$, we calculate the covariance matrix $\mathbf{V}_{\boldsymbol{\gamma}}$ of the marginal effects using: $\mathbf{V}_{\boldsymbol{\gamma}} = (\partial\mathbf{f}/\partial\boldsymbol{\beta})'\mathbf{V}_{\boldsymbol{\beta}}(\partial\mathbf{f}/\partial\boldsymbol{\beta})$, where $\mathbf{V}_{\boldsymbol{\beta}}$ is the covariance matrix of the reduced-form parameters.

[21] The interpretation according to which income effects dominates substitution effects is not valid here since the theoretical model is collective.

Table 2: Estimations of the parameters of the reduced-form models

	Model without domestic production				Model with domestic production			
Husband's domestic labor supply								
constant	_	_	_	_	7,025	(8,450)	6,559	(8,381)
husband's wage	_	_	_	_	0,010	(0,034)	0,011	(0,033)
wife's wage	_	_	_	_	0,090	(0,028)	0,089	(0,027)
age	_	_	_	_	-0,113	(0,351)	-0,107	(0,350)
age squared	_	_	_	_	0,003	(0,004)	0,002	(0,004)
education	_	_	_	_	-0,355	(0,229)	-0,341	(0,228)
region 2: Midwest	_	_	_	_	2,641	(1,027)	2,628	(1,027)
region 3: South	_	_	_	_	0,380	(1,000)	0,279	(0,976)
region 4: West	_	_	_	_	0,876	(1,152)	0,817	(1,144)
non-white	_	_	_	_	-1,442	(1,081)	-1,497	(1,072)
hispanic	_	_	_	_	-1,335	(1,394)	-1,471	(1,363)
week-end	_	_	_	_	6,128	(0,690)	6,123	(0,690)
Inverse Mills Ratio	_	_	_	_	-1,232	(2,673)	_	_
Wife's domestic labor supply								
constant	_	_	_	_	25,243	(14,467)	14,284	(9,387)
husband's wage	_	_	_	_	0,090	(0,028)	0,089	(0,027)
wife's wage	_	_	_	_	-0,086	(0,045)	-0,086	(0,045)
age	_	_	_	_	0,038	(0,449)	0,279	(0,385)
age squared	_	_	_	_	0,001	(0,006)	-0,002	(0,004)
education	_	_	_	_	-1,231	(0,461)	-0,856	(0,282)
region 2: Midwest	_	_	_	_	-1,594	(1,202)	-1,515	(1,200)
region 3: South	_	_	_	_	-0,884	(1,218)	-1,269	(1,160)
region 4: West	_	_	_	_	-1,027	(1,308)	-1,221	(1,295)
non-white	_	_	_	_	-1,015	(1,280)	-1,521	(1,185)
hispanic	_	_	_	_	0,955	(1,583)	0,396	(1,489)
week-end	_	_	_	_	6,234	(0,777)	6,229	(0,777)
Inverse Mills Ratio	_	_	_	_	-5,962	(5,712)	_	_
Husband's market labor supply								
constant	33,844	(3,164)	33,892	(3,155)	33,791	(3,164)	33,843	(3,154)
husband's wage	-0,056	(0,045)	-0,057	(0,045)	-0,051	(0,045)	-0,052	(0,045)
wife's wage	0,025	(0,051)	0,020	(0,050)	0,025	(0,051)	0,020	(0,050)
husband's wage squared	0,001	(0,001)	0,001	(0,001)	0,001	(0,001)	0,001	(0,001)
wife's wage square	0,001	(0,001)	0,001	(0,001)	0,001	(0,001)	0,001	(0,001)
cross product of wages	-0,001	(0,001)	-0,001	(0,001)	-0,001	(0,001)	-0,001	(0,001)
net expenditure	-0,001	(0,000)	-0,001	(0,000)	-0,001	(0,000)	-0,001	(0,000)
age	0,111	(0,127)	0,114	(0,127)	0,111	(0,127)	0,113	(0,127)
age squared	-0,001	(0,001)	-0,001	(0,001)	-0,001	(0,001)	-0,001	(0,001)
education	0,490	(0,103)	0,497	(0,102)	0,490	(0,103)	0,497	(0,102)
region 2: Midwest	0,688	(0,390)	0,676	(0,389)	0,687	(0,390)	0,675	(0,389)
region 3: South	0,204	(0,368)	0,240	(0,361)	0,205	(0,368)	0,241	(0,361)
region 4: West	0,048	(0,427)	0,059	(0,426)	0,046	(0,427)	0,057	(0,426)
non-white	-1,350	(0,317)	-1,321	(0,312)	-1,349	(0,317)	-1,321	(0,312)
hispanic	-1,346	(0,449)	-1,298	(0,440)	-1,342	(0,449)	-1,294	(0,440)
Inverse Mills Ratio	0,521	(1,027)	_	_	0,519	(1,027)	_	_
Wife's market labor supply								
constant	29,092	(5,236)	27,969	(3,322)	29,125	(5,235)	27,971	(3,291)
husband's wage	-0,209	(0,047)	-0,209	(0,047)	-0,206	(0,047)	-0,207	(0,047)
wife's wage	0,241	(0,055)	0,241	(0,054)	0,239	(0,054)	0,240	(0,054)
husband's wage squared	0,001	(0,001)	0,001	(0,001)	0,000	(0,001)	0,000	(0,001)
wife's wage square	-0,006	(0,001)	0,006	(0,001)	-0,006	(0,001)	-0,006	(0,001)
cross product of wages	0,006	(0,001)	0,006	(0,001)	0,006	(0,001)	0,006	(0,001)
net expenditure	0,000	(0,000)	0,000	(0,000)	0,000	(0,000)	0,000	(0,000)
age	0,168	(0,161)	0,194	(0,134)	0,167	(0,161)	0,194	(0,134)
age squared	-0,003	(0,002)	-0,003	(0,002)	-0,003	(0,002)	-0,003	(0,002)
education	0,557	(0,179)	0,598	(0,112)	0,555	(0,179)	0,113	(5,308)
region 2: Midwest	0,644	(0,412)	0,644	(0,412)	0,644	(0,412)	0,644	(0,412)
region 3: South	1,370	(0,403)	1,338	(0,383)	1,372	(0,403)	1,339	(0,384)
region 4: West	0,062	(0,461)	0,037	(0,452)	0,064	(0,460)	0,038	(0,452)
non-white	-0,180	(0,369)	-0,226	(0,330)	-0,178	(0,369)	-0,331	(0,680)
hispanic	0,092	(0,523)	0,031	(0,473)	0,095	(0,523)	0,474	(0,069)
Inverse Mills Ratio	-0,492	(1,892)	_	_	-0,504	(1,892)	_	_

Note: standard errors are in parentheses

1984). The Hispanic and non-white dummies are not significantly different from zero. The weekend days dummy is positive and large. In other words, spouses devote more time to household chores during weekend.

Finally, for all the models, we tested the restriction (13e), namely the constraint of symmetry in spouses' domestic labor supplies. First the reduced-form labor supply equations, (4)-(7), has been estimated without imposing the constraint $A_2 = B_2$ and a t-ratio has been computed. This statistic is asymptotically distributed as a standardized normal. For the SUR estimation taking into account selection, its value is equal to -0.388, then we do not reject the hypothesis of symmetry at usual levels. Moreover, data confirms that domestic labor supplies are independent of nonlabor income, as the theoretical model says. The reduced-form labor supply equations, (4)-(7), in fact, has been estimated including net expenditure as explanatory variable also in domestic labor supplies. Net expenditure is never significant, for both the husband and the wife, in domestic labor supply equations. The corresponding t-ratios are equal to 0.425 and -0.754 for the husband's and the wife's equations, respectively.

To conclude, the reduced-form estimations obtained by the SUR method (accounting for sample selection or not) are quite convincing in view of the past literature. We can now turn to the estimations of the structural parameters.

5.2 The structural-form models

The estimates of the structural parameters are reported in Table 3 and are derived using the formulae previously given. Concerning the Marshallian labor supply equations, the estimates for the model with domestic production and those for the model without domestic production are of the same sign and the same order of magnitude. This is expected because the cross-wage terms in the domestic labor supply equations are small.

Whatever the model we consider, an increase in husband's wage rate has virtually no impact on his market hours while the wife's labor supply is clearly backward bending, with a cusp point at a relatively large level of wage rate (around fifty dollars). These results are conformed to intuition and to some empirical estimates obtained with the unitary approach (see the discussion above). Moreover, the slope of Engel curves is negative for both the husband and the wife. This represents an interesting test of the collective approach. If it is admitted because uncontroversial that leisure is a normal good, then the parameters α_3 (or α_3^*) and β_3 (or β_3^*) must be negative. As previously seen, the negativity of these parameters is guaranteed if

Table 3: Estimations of the parameters of the structural-form model (estimates when accounting for sample selection)

	Model without domestic production		Model with domestic production	
Estimates of the parameters of the husband's share of income				
husband's wage	-33,788	(31,043)	-25,304	(19,617)
wife's wage	-17,637	(36,503)	-80,504	(47,512)
husband's wage squared	0,082	(0,157)	0,086	(0,177)
wife's wage square	-0,389	(0,737)	-0,409	(0,729)
cross product of wages	0,913	(0,788)	0,961	(0,780)
net expenditure	0,923	(0,094)	0,909	(0,102)
Estimates of the parameters of the husband's Marshallian labor supply				
husband's wage	-0,104	(0,058)	-0,077	(0,060)
husband's wage squared	0,001	(0,001)	0,001	(0,001)
husband's income share	-0,001	(0,000)	-0,001	(0,000)
Estimates of the parameters of the wife's Marshallian labor supply				
wife's wage	0,350	(0,236)	0,499	(0,334)
wife's wage squared	-0,004	(0,005)	-0,004	(0,004)
wife's income share	-0,006	(0,006)	-0,005	(0,004)
Estimates of the marginal effects of the husband's welfare				
husband's wage	28,900	(13,731)	40,436	(6,579)
wife's wage	-11,802	(24,738)	-74,314	(34,899)
net expenditure	0,923	(0,094)	0,909	(0,102)
Estimates of the marginal effects of the wife's welfare				
husband's wage	14,834	(13,731)	0,251	(6,304)
wife's wage	55,535	(24,738)	101,942	(34,828)
net expenditure	0,077	(0,094)	0,091	(0,102)

Notes: In the model with domestic production, the parameters and the marginal effects are computed for white, non-hispanic persons living in the Northeast region with 12 years of education and the average values of wage rates and non-labor income. The dummy variable for weekdays is set at 2/7. Standard errors are in parentheses.

the right-hand side of expressions (11g) (or (17g)) and (11h) (or (17h)) is negative, which is far from being trivial properties.

For the estimates of the parameters of the husband's income share, and whatever the model we consider, net expenditure has a positive, greater than half, and significant effect on the fraction of total income received by the husband. This result is in line with previous studies by Blundell, Chiappori, Magnac and Meghir (2007), Bloemen (2010), Chiappori, Fortin and Lacroix (2002), and Donni (2007) that ignore domestic production.Overall, this empirical observation seems to be remarkably robust across studies.[22] Be that as it may, the other parameters of the husband's income share

[22] All the studies mentioned above suppose that net expediture has a linear effect on market

are less precisely estimated and differ moderately for the two models we examine.

More important are the marginal effects of wage rates on spouses' welfare. For the model without domestic production, and computed at the average point of the sample, the marginal effect of a one-dollar increase in the husband's (resp. wife's) wage rate increases (resp. reduces) the husband's welfare by about twenty-nine dollars (resp. twelve dollars). For the model with household production, nevertheless, the welfare effects of a one dollar increase in wage rate are rather different. Firstly, the negative effect of the wife's wage rate on the husband's welfare is much more marked. To be precise, the marginal effect of a one-dollar increase in the wife's wage rate reduces the husband's welfare by about seventy four dollars, which is considerable. One interpretation of these differences is that the collective model without domestic production ignores the fact that wage rates have also an indirect effect on husband's leisure through variations in domestic activities. Since spouses' time inputs are substitute in the household technology, the decline in husband's leisure – and, consequently, in his utility – due to an increase in wife's wage rate is thus underestimated when domestic production is omitted. This mechanism was already suggested by Donni (2008). Secondly, the positive effect of the husband's wage rate on the husband's welfare is much more marked in the model with domestic production: a one-dollar increase in husband's wage rate leads to a fourty dollars increase in husband's welfare. The results go in the same direction, even if less pronounced, when the effects of wage rates on the wife's welfare are examined. Nevertheless, the standard errors are excessively large so that it is not possible to draw definitive conclusions.

6 Conclusion

In this work, we focused on the collective model of labor supply introducing household production. One of our aims was to examine whether home production does matter or not. We demonstrate a new identification result and show, in fact, that incorporating domestic production does not modify radically the conclusions that can be derived from the traditional collective model of labor supply.

The omission of domestic production in the collective model of labor supply seems to hidden some important transfers within the household that may result from variations in spouses' wage rate. In fact, when domestic production is omitted, the (generally) positive effect of an increase in the husband's (resp. wife's) wage rate on

labor supply. Other studies by Fortin and Lacroix (1997) and Donni et Moreau (2007) do not furnish precise estimation of the structural parameters.

his (resp. her) own welfare is underestimated while the (generally) negative effect on her (resp. his) partner's welfare is overestimated. This conclusion, however, must be balanced by the fact that the parameters are not estimated with a great precision. The sensitivity of domestic hours to wage rates plays a major role when examining distortions due to the omission of domestic activities. It is clear that in our data (and in many other data on time use) domestic labor supply is rather inelastic. This may explain why distortions in welfare measurement are not very significant.

To improve the precision of the estimates, next developments of this work should explicitly consider corner solutions in the collective model with household production and model the decision to participate in the labor market. For the case of market behavior, identification results have previously been generalized. Because spouses' wage rates (if observed) are not equal to marginal productivities, domestic labor supply must be expressed as a function of shadow wage rates that represent the price of leisure. Such an extension is necessary to increase the number of observations as well as the dispersion in market working time. This is the objective of future work.

Appendix

Proof of Proposition 4

To begin with, we define total individual labor supply functions in this context of complete market for domestic produced good as follows:

$$\begin{aligned} L^1 &= F^1(w_1, \Psi^1(w_1, w_2, y, \mathbf{d}), \mathbf{d}), \\ L^2 &= F^2(w_2, y + \Pi(w_1, w_2, \mathbf{d}) - \Psi^1(w_1, w_2, y, \mathbf{d}), \mathbf{d}). \end{aligned}$$

Then we calculate the derivatives of total labor supply functions with respect to the partner's wage and nonlabor income, that is,

$$\begin{aligned} L^1_{w_2} &= F^1_{\Psi^1} \cdot \Psi^1_{w_2}, \\ L^2_{w_1} &= F^2_{\Psi^2} \cdot \left(\Pi_{w_1} - \Psi^1_{w_1}\right), \end{aligned}$$

and

$$\begin{aligned} L^1_{y} &= F^1_{\Psi^1} \cdot \Psi^1_{y}, \\ L^2_{y} &= F^2_{\Psi^2} \cdot \left(1 - \Psi^1_{y}\right). \end{aligned}$$

where the term $\partial\Pi/\partial w_1 = -t^1(w_1, w_2, \mathbf{d})$ from Hotelling's lemma. Taking the same notation as Chiappori (1988, 1992), we define:

$$A = \frac{L^1_{w_2}}{L^1_y} = \frac{\Psi^1_{w_2}}{\Psi^1_y}, \tag{A-1}$$

$$B = \frac{L^2_{w_1}}{L^2_y} = -\frac{t^1 + \Psi^1_{w_1}}{1 - \Psi^1_y}. \tag{A-2}$$

where the left-hand side is observable by the econometrician. Then, differentiating these expressions, we obtain

$$\begin{aligned}
\Psi^1_{w_2 w_1} &= A_{w_1}\Psi^1_y + A\Psi^1_{yw_1}, \\
\Psi^1_{w_2 y} &= A_y\Psi^1_y + A\Psi^1_{yy}, \\
\Psi^1_{w_1 w_2} &= -t^1_{w_2} - B_{w_2}(1 - \Psi^1_y) + B\Psi^1_{yw_2}, \\
\Psi^1_{w_1 y} &= -t^1_y - B_y(1 - \Psi^1_y) + B\Psi^1_{yy}.
\end{aligned}$$

which constitutes with (A-1) and (A-2) a system of six equations and seven unknowns. In spite of the fact that the number of unknowns is greater than the number of equations, this system can be solved with respect to the derivatives of the sharing function, that is,

$$\Psi^1_y = \frac{AB_y - B_{w_2} - t^1_{w_2}}{A_{w_1} + AB_y - B_{w_2} - A_y B},$$

and

$$\begin{aligned}
\Psi^1_{w_1} &= -t^1 - B(1 - \Psi_y) \\
\Psi^1_{w_2} &= A\Psi_y.
\end{aligned}$$

Using a similar approach, the derivatives of Ψ^2 can also be retrieved. □

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