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On the importance of household production in collective models: Evidence from U.S. data

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May 2010

Forschungsinstitut
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ABSTRACT

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

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 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.

JEL Classification: D13, J21, J22

Keywords: collective model, market labor supply, domestic labor supply, household production, identification, ATUS

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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 labour supply, developed 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. Furthermore, Chiappori, Fortin and Lacroix (2002) introduces the notion of distribution factors, defined as variables that influence the sharing of resources within the household without affecting preferences or the budget constraint, and thereby complete the preceding identification result.[1]

The initial formulation of the collective model of labor supply – what we call Chiappori's (1992) model henceforth – 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 reflects 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. Going one step further, 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

[1] See Chiappori and Donni (2010) for a recent survey of the collective model literature.

of her/his partner. Yet this result is essentially theoretical. It says nothing on the actual size of the distortions, due to the omission of domestic production, in welfare analysis that are carried out with real data.

The collective model of labor supply has, however, been extended to 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. This is what we refer to as Chiappori's (1997) model henceforth. He then shows that, in the case of marketable domestic production, and if there is at least one distribution factor, the sharing rule can be completely identified (up to a constant) from the estimation of market and domestic labor supply functions.[2] One of the very rare estimations of this model is proposed by Rapoport, Sofer and Solaz (2010) with French data.[3] 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).[4] They then recover the parameters of the sharing rule.

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 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

[2]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.

[3]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).

[4]The theory of collective models with domestic production, up to now, does not deal with the spouses' decision to participate in the labor market. Regarding the case without domestic production, see Donni (2003, 2007) for a theoretical and empirical study of the decision to participate.

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 Chiappori (1997). The method of estimation, however, is quite different from that of Rapoport, Sofer and Solaz (2010). The first divergence is that a complete system of market and domestic labor supply equations is estimated, and not only 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 modelled 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' total labor supply (i.e., the sum of domestic labor supply t^i and market labor supply h^i), with $i = 1, 2$.[5] The utility is represented by a strictly quasiconcave, monotonic, and sufficiently smooth function, that is,

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

where $\mathbf{d}$ is a vector of socio-demographic factors that may affect individual preferences.[6] As a convention, we also suppose 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 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 labour supply, namely, Chiappori (1992)'s model without domestic production and Chiappori (1997)'s model with domestic production.

2.1 The model without household production

If there is no domestic production, total labor supply L^i coincides with market labor supply h^i. Moreover, all the consumption of household members is purchased on the market. If taxation is ignored, 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' (market) labor supply, w_i are individual wage rates and y is non-labor income (or net expenditure). 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, non labor income y is shared among household members according to a sharing rule. At the second stage, each individual separately allocates her/his income to own consumption and leisure in a way that maximize her/his own utility subject to an individual budget constraint. Formally, the result is stated as follows.

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

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

Lemma 1. *The Pareto optimal allocations* (C^i, L^i) *are solution of the following decentralized programs: each household member maximizes her/his utility subject to her/his budget constraint,*

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

subject to:

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

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

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

for some Marshallian labor supply functions F^i.

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 rule $\Phi^i(w_1, w_2, y, \mathbf{d})$ 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 (2010) use the sex ratio in the surrounding population as argument of the sharing rule. 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 makes 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 rule 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's share of non labor income. This property is restrictive and can be empirically tested for sufficiently flexible functional forms; see Chiappori (1988, 1992). In addition, the sharing rule can be generically identified 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

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

and define:

$$A = \frac{L_{w_2}^1}{L_y^1} \qquad \text{and} \qquad B = \frac{L_{w_1}^2}{L_y^2},$$

so that we can define:

$$\alpha = \frac{AB_y - Bw_2}{A_{w_1} + AB_y - Bw_2 - A_y B}, \qquad \text{and} \qquad \beta = (1 - \alpha).$$

provided that

$$A_{w_1} + AB_y \neq A_y B - Bw_2. \tag{R–2}$$

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 <u>one</u> 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 can be explained as follows. Changes either in non-labor 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 non-labor 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 rule itself 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).

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. Total working time of individual i is then given by

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

Moreover, we follow Gronau (1977, 1980) and suppose that the domestic good can be exchanged on a competitive market at a constant price. In other words, total consumption of individual i can be divided between consumption purchased on the market and consumption produced within the household. The quantity of purchased goods is denoted by x^i and the quantity of produced goods by z^i. Hence total consumption of individual i is simply equal to

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

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, 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 non-labor 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.

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:

$$t^i = g^i(t_1, t_2, \mathbf{d}).$$

B. *At the second stage, each household member maximizes her/his utility subject to her/his 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 $\Psi^i(y, w_1, w_2, \mathbf{d})$, *such that* $\sum_i \Psi^i(y, w_1, w_2, \mathbf{d}) = y + \Pi(w_1, w_2, \mathbf{d})$. *Individual market labor supply functions can be written as:*

$$h^i = F^i(w_i, \Psi^i(y, w_1, w_2, \mathbf{d}), \mathbf{d}) - g^i(t_1, t_2, \mathbf{d})$$

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

Proof. This result is also a straightforward implication of the second theorem of welfare economics in an economy with production; see also Chiappori (1997). □

Our new theoretical result here is that the sharing rule up can be identified up to an additive constant even in absence of distribution factors. First, as previously, we suppose that

$$L^1_y \cdot L^2_y \neq 0$$

and define:

$$A^* = \frac{L^1_{w_2}}{L^1_y} \qquad \text{and} \qquad B^* = \frac{L^2_{w_1}}{L^2_y}. \tag{R–1′}$$

In addition, if

$$A^*_{w_1} + A^* B^*_y \neq A^*_y B^* + B^*_{w_2}, \tag{R–2′}$$

we define:

$$\alpha^* = \frac{A^* B^*_y - B^*_{w_2} - t^1_{w_2}}{A^*_{w_1} + A^* B^*_y - B^*_{w_2} - A^*_y B^*} \qquad \text{and} \qquad \beta^* = 1 - \alpha^*.$$

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*

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

and those of individual 2's share by

$$\Psi^2_y = \beta^*, \quad \Psi^1_{w_2} = -t^2 - A^*\alpha^*, \quad \textit{and} \quad \Psi^1_{w_1} = B^*\beta^*.$$

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) because the profit function itself is 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 in the proposition above requires the estimation of both market and domestic labor supply functions. In contrast, Chiappori (1997) and Rapoport, Sofer and Solaz (2010) in a collective model with distribution factors show that the sharing rule can be retrieved from the estimation of the sole total labor supply functions.

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 will be 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 with public consumption provided that the shadow price of consumption is not excessively flexible. To take a simple 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 the same and equal to γ, while 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 can be omitted of the analysis and the framework with private consumption presented here is still valid.[7]

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,

$$t^1 = A_0(\mathbf{d}) + A_1 w_1 + A_2 w_2 + u_1, \tag{3}$$

$$t^2 = B_0(\mathbf{d}) + B_1 w_2 + B_2 w_1 + u_2, \tag{4}$$

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,

$$h^1 = a_0(\mathbf{d}) + a_1 w_1 + a_2 w_2 + a_3 w_1^2 + a_4 w_2^2 + a_5 w_1 w_2 + a_6 y + u_3, \tag{5}$$

$$h^2 = b_0(\mathbf{d}) + b_1 w_1 + b_2 w_2 + b_3 w_1^2 + b_4 w_2^2 + b_5 w_1 w_2 + b_6 y + u_4, \tag{6}$$

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.[8] For the sake of our discussion, we suppose that stochastic terms represent unobservable heterogeneity in preferences, in the sharing rule 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,

[7] The discussion here is inspired by Browning, Chiappori and Lewbel (2010).

[8] 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.

the system of four equations (3)–(6) is estimated and the sharing rule is identified using all the information about spouses' market and domestic labor behavior. In the latter case, the system of only two equations (5)–(6) is estimated. The uniqueness of the parameters of the sharing rule (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 rule are defined as a combination of the parameters of the reduced form of labor supply equations.

3.2 Structural-Form Model 1: Chiappori's (1992) Model

If there is no domestic production, we can show that the unique specification for the husband's share of income compatible with (5)–(6) is given by

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

and for the wife's share of income by

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

where $\kappa_0(\mathbf{d})$ is some unidentified (possibly stochastic) function while[9]

$$\kappa_1 = a_5 b_1 / (a_6 b_5 - a_5 b_6), \tag{7a}$$
$$\kappa_2 = a_2 b_5 / (a_6 b_5 - a_5 b_6), \tag{7b}$$
$$\kappa_3 = a_5 b_3 / (a_6 b_5 - a_5 b_6), \tag{7c}$$
$$\kappa_4 = a_4 b_5 / (a_6 b_5 - a_5 b_6), \tag{7d}$$
$$\kappa_5 = a_5 b_5 / (a_6 b_5 - a_5 b_6), \tag{7e}$$
$$\kappa_6 = a_6 b_5 / (a_6 b_5 - a_5 b_6), \tag{7f}$$

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

$$L^1 = \alpha_0(\mathbf{d}) + \alpha_1 w_1 + \alpha_2 w_1^2 + \alpha_3 \Phi^1(w_1, w_2, y, \mathbf{d}), \tag{8}$$
$$L^2 = \beta_0(\mathbf{d}) + \beta_1 w_2 + \beta_2 w_2^2 + \beta_3 \Phi^2(w_1, w_2, y, \mathbf{d}), \tag{9}$$

[9] We do not explicitly derive the structural parameters here, which would be fastidious. The reader can easily check that incorporating (7) and (10) in (8) and (9) gives (5) and (6). Of course, the same remark applies for the other model.

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

$$\alpha_0(\mathbf{d}) = a_0(\mathbf{d}) + u_3 - (a_6 - a_5 b_6/b_5)\,\kappa_0(\mathbf{d}), \tag{10a}$$
$$\beta_0(\mathbf{d}) = b_0(\mathbf{d}) + u_4 + (b_6 - b_5 a_6/a_5)\,\kappa_0(\mathbf{d}), \tag{10b}$$

while

$$\alpha_1 = a_1 - a_5 b_1/b_5, \tag{10c}$$
$$\beta_1 = b_2 - b_5 a_2/a_5, \tag{10d}$$
$$\alpha_2 = a_3 - a_5 b_3/b_5, \tag{10e}$$
$$\beta_2 = b_4 - b_5 a_4/a_5, \tag{10f}$$
$$\alpha_3 = a_6 - a_5 b_6/b_5, \tag{10g}$$
$$\beta_3 = b_6 - b_5 a_6/a_5. \tag{10h}$$

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 non-labor income on husband's utility can be written as:

$$\Delta U_1 = \lambda_1 \times (L_1 + \kappa_1 + 2\kappa_3 w_1 + \kappa_5 w_2) \times \Delta w_1, \tag{11a}$$
$$\Delta U_1 = \lambda_1 \times (\kappa_2 + 2\kappa_4 w_2 + \kappa_5 w_1) \times \Delta w_2, \tag{11b}$$
$$\Delta U_1 = \lambda_1 \times \kappa_6 \times \Delta y, \tag{11c}$$

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: Chiappori's (1997) Model

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 given by

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

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

$$\pi_1^* = -A_0(\mathbf{d}) - u_1, \tag{12a}$$
$$\pi_2^* = -B_0(\mathbf{d}) - u_2, \tag{12b}$$
$$\pi_3^* = -A_1/2, \tag{12c}$$
$$\pi_4^* = -B_1/2, \tag{12d}$$
$$\pi_5^* = -A_2 = -B_2 = -C, \tag{12e}$$

where the last equality is a testable restriction. This profit function is locally regular (that is, 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 (3)–(6) 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

$$\kappa_1^* = \kappa_1\left(1+\frac{a_5+a_6b_1+a_6C}{a_5b_1}C\right) - A_0(\mathbf{d}) - u_1, \tag{13a}$$

$$\kappa_2^* = \kappa_2\left(1+\frac{b_5+a_2b_6+b_6C}{a_2b_5}C\right), \tag{13b}$$

$$\kappa_3^* = \kappa_3\left(1+\frac{a_6}{a_5}C\right) - \frac{A_1}{2}, \tag{13c}$$

$$\kappa_4^* = \kappa_4\left(1+\frac{b_6}{b_5}C\right), \tag{13d}$$

$$\kappa_5^* = \kappa_5\left(1+\frac{b_6}{b_5}C\right), \tag{13e}$$

$$\kappa_6^* = \kappa_6\left(1+\frac{b_6}{b_5}C\right). \tag{13f}$$

These relations put the emphasis on the differences between the parameters of the sharing rule 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 non-labor 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:

$$L^1 = \alpha_0^*(\mathbf{d}) + \alpha_1^* w_1 + \alpha_2^* w_1^2 + \alpha_3^* \Psi^1(w_1, w_2, y, \mathbf{d}), \tag{14}$$

$$L^2 = \beta_0^*(\mathbf{d}) + \beta_1^* w_2 + \beta_2^* w_2^2 + \beta_3^* \Psi^2(w_1, w_2, y, \mathbf{d}), \tag{15}$$

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

$$\alpha_0^*(\mathbf{d}) = a_0(\mathbf{d}) + u_3 - \frac{a_6b_5 - a_5b_6}{b_5 + Cb_6}\kappa_0^*(\mathbf{d}) + (A_0(\mathbf{d}) + u_1), \tag{16a}$$

$$\beta_0^*(\mathbf{d}) = b_0(\mathbf{d}) + u_4 - \frac{a_5b_6 - a_6b_5}{a_5 + Ca_6}\left(\pi_0^*(\mathbf{d}) - \kappa_0^*(\mathbf{d})\right) + (B_0(\mathbf{d}) + u_2), \tag{16b}$$

while

$$\alpha_1^* = a_1 - \frac{a_5 b_6 - a_6 b_5}{b_5 + C b_6}\left(A_0(\mathbf{d}) + u_1\right) - \frac{a_5 + C a_6}{b_5 + C b_6}\left(b_1 + C\right) + A_1, \tag{16c}$$

$$\beta_1^* = b_2 + \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}\left(B_0(\mathbf{d}) + u_2\right) - \frac{b_5 + C b_6}{a_5 + C a_6}\left(a_2 + C\right) + B_1, \tag{16d}$$

$$\alpha_2^* = a_3 - \frac{a_5 b_6 - a_6 b_5}{b_5 + C b_6}\frac{A_1}{2} - \frac{a_5 + C a_6}{b_5 + C b_6} b_3, \tag{16e}$$

$$\beta_2^* = b_4 + \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}\frac{B_1}{2} - \frac{b_5 + C b_6}{a_5 + C a_6} a_4, \tag{16f}$$

$$\alpha_3^* = \frac{a_6 b_5 - a_5 b_6}{b_5 + C b_6}, \tag{16g}$$

$$\beta_3^* = \frac{a_5 b_6 - a_6 b_5}{a_5 + C a_6}. \tag{16h}$$

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

$$\Delta U_1^* = \lambda_1^* \times \left(L_1 + \kappa_1^* + 2\kappa_3^* w_1 + \kappa_5^* w_2\right) \times \Delta w_1, \tag{17a}$$

$$\Delta U_1^* = \lambda_1^* \times \left(\kappa_2^* + 2\kappa_4^* w_2 + \kappa_5^* w_1\right) \times \Delta w_2, \tag{17b}$$

$$\Delta U_1^* = \lambda_1^* \times \kappa_6^* \times \Delta y. \tag{17c}$$

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 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 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.

Our initial 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.[10] 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 definition of domestic work includes household activities like housework (interior cleaning, laundry, etc.), food and drink preparation, and interior and exterior maintenance. Because the ATUS collects information on household activities for only one member in the family, we know domestic labor supply for only 1413 women and 1230 men. For 1800 households we do not know domestic labor supply neither for the husband

[10] 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
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
Unemployment rate	5,418	0,983

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 (expressed in years), the ethnicity (dummy variable: Hispanic or not), and the race (dummy variable: non-white or white). We also use information regarding the region of residence (dummy variables: Midwest, South, West; reference is Northeast), and the housing tenure (dummy variable: owned or not).

The availability of information on the annual family net expenditure was obtained by the imputation of this value from the Current Expenditure Survey (CES), for the year 2003 to the first quarter of 2006. We selected a subsample of 683 married, childless couples in which both members have a job. 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, the dummy variable for housing tenure, the unemployment rate by state and by year, household non labor 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 used for identification.

4.2 Estimation Method

In what follows, we consider the estimation of the complete system, (3)–(6), of reduced-form market and domestic labor supply equations.[11] 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 have $N_1 < N$ observations for which male domestic labor time is reported but not female domestic labor time, $N_2 < N$ observations for which female domestic labor time is reported and not male labor time, and $N_3 < N$ observations with only market labor time. Furthermore, given that we concentrate our analysis of labor supply upon the subsample of households in the workforce, we face a sample selection problem. 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, including inverse Mill's ratio, as the following system of four linear equations:

$$y_{ij} = \mathbf{x}'_{ij}\boldsymbol{\beta}_j + \sigma_j \lambda_i + u_{ij} \text{ with } j = 1, 2, 3, 4,$$

where y_{ij} represents the explained variable j 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 $y_4 = h_2$, $\mathbf{x}_{ij}$ is the vector of explanatory variables, λ_i the inverse Mill's

[11] The system (5)–(6) can be seen as a particular case of the complete system and its estimation is not discussed here.

ratio, and $\boldsymbol{\beta}_j$ and σ_j the corresponding vector of parameters. For the domestic labor supply equations, the vector of explanatory variables $\mathbf{x}_{ij}$ 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, 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 $\mathbf{x}_{ij}$ 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. As is explained below, education is used as an instrument for wage rates and is excluded from labor supply equations; it is incorporated in these equations only when wage rates are not instrumented.[12]

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. Furthermore, we have reasons to believe that wage rates are endogenous (because of the way of constructing them, in particular (Borjas, 1980)). The reduced-form equations are thus estimated alternatively by the SUR (Zellner, 1962) and the 3SLS (Zellner and Theil, 1962) methods, the latter method is to account for the probable endogeneity of wage rates. In the discussion that follows we focus on the description of the 3SLS method; the SUR method is simply a particular case.

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 Mill's ratio $\hat{\lambda}_i$ 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. Then the wage rates, the squared wage rates and the cross product of wage rates that enter market labor supply equations are regressed on the same variables (except net expenditure) and the Inverse Mill's ratio. The vector of explanatory variables $\mathbf{x}_{ij}$ with the fitted values obtained from

[12] For other studies that use education as an excluded instrument, see Bourguignon and Magnac (1990) or Pencavel (1998).

this preliminary stage instead of the current variables is denoted by $\hat{\mathbf{x}}_{ij}$.

In the second stage of the estimation process, the y_{ij}'s are regressed on $\hat{\mathbf{x}}_{ij}$ using the OLS method to obtain estimates $\hat{\boldsymbol{\beta}}_j$ and then compute

$$\hat{\omega}_{jk} = \frac{\sum_{i \in \mathcal{N}_{jk}} \hat{u}_{ij}\hat{u}_{ik}}{\#\mathcal{N}_{jk}} \text{ for } j, k = 1, \ldots, 4,$$

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

$$\hat{u}_{ij} = y_{ij} - \mathbf{x}'_{ij}\hat{\boldsymbol{\beta}}_j - \hat{\sigma}_j\hat{\lambda}_{ij},$$

and $\mathcal{N}_{jk}$ is the set of indexes i such that variables j and k are both observed.[13] With the usual staking of observations, each reduced-form equation can be written as:

$$\mathbf{y}_j = \hat{\mathbf{X}}_j\boldsymbol{\beta}_j + \sigma_j\hat{\boldsymbol{\lambda}}_j + \mathbf{u}_j,$$

where $\mathbf{y}_j$ is the vector of explained variables, $\hat{\mathbf{X}}_j$ is is the matrix of fitted explanatory variables, $\hat{\boldsymbol{\lambda}}_j$ is the vector of inverse of Mill's ratio, and $\mathbf{u}_j$ is the vector of stochastic terms. 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 $\hat{\mathbf{Z}}$ below is block diagonal, the system of reduced-form equations can be written as:

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

or

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

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

[13] The operator # is the number of elements of the set. Precisely, $\#\mathcal{N}_{jk} = N_1$ if j or $k = 1$, j and $k \neq 2$, $\#\mathcal{N}_{jk} = N_2$ if j or $k = 2$, j and $k \neq 1$, $\#\mathcal{N}_{jk} = N_1 + N_2 + N_3 = N$ if j or $k = 3$ or 4 (and $\#\mathcal{N}_{jk} = 0$ if j or $k = 1$ or 2 and $j \neq k$ 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 gain 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 $\hat{\omega}_{12}$. The 3SLS estimator is given by

$$\hat{\boldsymbol{\theta}}_{3\text{SLS}} = (\hat{\mathbf{Z}}'\hat{\Omega}^{-1}\hat{\mathbf{Z}})^{-1}\hat{\mathbf{Z}}'\hat{\Omega}^{-1}\mathbf{y}.$$

The estimation procedure is the same when the constraint of symmetry is imposed except that the matrix $\hat{\mathbf{Z}}$ is not block diagonal. The SUR estimator is obtained by replacing $\hat{\mathbf{x}}_{ij}$ by $\mathbf{x}_{ij}$ in the 3SLS procedure. 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. 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 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 $\sigma_j = 0$ for $j = 1, \ldots, 4$.

5 Estimation Results and Discussion

5.1 The reduced-form models

The estimation results for the reduced-form labor supply equations, (3)-(6), obtained by the 3SLS method (accounting for sample selection) are presented in Table 2. The estimated parameters and their standard deviations are reported for the two-equation system and the four-equation system. Like it can be easily seen, the

estimation results whatever the model we consider are very similar, which is not really surprising as the parametric specifications of the market labor supply equations in both cases are the same. Only the estimation methods are different.[14]

The main results can be summarized as follows. For the market labor supply equations, and whatever the model we consider, net expenditure has a negative, which was expected, but not significant impact for both the husband and the wife. Overall, the parameters concerning wage rates as well as socio-demographic variables are not precisely estimated. Considering the collective model with domestic production for instance, the marginal effect of the wife's (husband's) wage rate on her (his) market time computed at the average point of the sample (not reported in the table) is equal to 0.453 (-0.101) with a standard deviation of 0.353 (1.240).[15] For the domestic labor supply equations, it appears that the standard deviations of the estimates are excessively large too. On the whole, it seems that instruments are not sufficiently strong to provide precise estimations of the parameters. Therefore we will turn to the estimations obtained by the SUR method which are exhibited on Table 3.

First of all, note that the estimates are quite different from, and more significant than, those obtained by the 3SLS method.[16] Regarding the market labor supply equations, net expenditure has now 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, the marginal effect of the wife's (husband's) wage rate on her (his) market time, computed at the average point of the sample, is equal to 0.153 (-0.040) with a standard deviation of 0.023 (0.017), while the direct elasticity of wife's (husband's) market labor supply is thus equal to 0.066 (-0.019). The estimates are actually conformed to what is generally obtained in the empirical literature based on U.S.

[14] Technically, empirical results for reduced-form market labor supply equations would be the same if $\hat{\omega}_{13} = \hat{\omega}_{14} = \hat{\omega}_{23} = \hat{\omega}_{24} = 0$.

[15] 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.

[16] Explanatory variables in SUR estimations include education because this variable has not to be used as an instrument for wage rates. Note that education has a significant effect on market labor supply, which seems to invalidate it as an instrument.

Table 2: Estimations of the collective model of labor supply with and without domestic production: estimates obtained by the 3SLS method with accounting for sample selection

	Chiappori (1992)'s model		Chiappori (1997)'s model	
	Estimated parameters and standard deviation of husband's domestic labor supply			
constant	_	_	6,061	(7,812)
husband's wage	_	_	-0,013	(0,102)
wife's wage	_	_	-0,122	(0,129)
age	_	_	-0,072	(0,351)
age squared	_	_	0,003	(0,004)
education	_	_	_	_
region 2 dummy	_	_	2,284	(1,052)
region 3 dummy	_	_	0,473	(1,032)
region 4 dummy	_	_	1,311	(1,163)
non-white dummy	_	_	-1,092	(1,131)
hispanic dummy	_	_	-1,115	(1,439)
week-end dummy	_	_	6,118	(0,695)
Inverse Mills Ratio	_	_	-5,146	(3,193)
	Estimated parameters and standard deviation of wife's domestic labor supply			
constant	_	_	-2,408	(10,589)
husband's wage	_	_	-0,122	(0,129)
wife's wage	_	_	0,002	(0,229)
age	_	_	0,572	(0,421)
age squared	_	_	-0,006	(0,005)
education	_	_	_	_
region 2 dummy	_	_	-1,589	(1,260)
region 3 dummy	_	_	-1,838	(1,241)
region 4 dummy	_	_	-1,346	(1,340)
non-white dummy	_	_	-2,292	(1,340)
hispanic dummy	_	_	-0,368	(1,640)
week-end dummy	_	_	6,178	(0,792)
Inverse Mills Ratio	_	_	7,237	(5,273)
	Estimated parameters and standard deviation of husband's market labor supply			
constant	32,286	(7,221)	32,573	(7,218)
husband's wage	-0,979	(0,947)	-0,949	(0,946)
wife's wage	1,773	(1,186)	1,718	(1,185)
husband's wage squared	0,016	(0,021)	0,015	(0,021)
wife's wage square	-0,044	(0,021)	-0,043	(0,021)
education	_	_	_	_
cross product of wages	0,012	(0,018)	0,012	(0,018)
net expenditure	-0,001	(0,001)	-0,001	(0,001)
age	0,132	(0,222)	0,126	(0,222)
age squared	-0,002	(0,003)	-0,002	(0,003)
region 2 dummy	1,499	(0,576)	1,491	(0,576)
region 3 dummy	0,544	(0,537)	0,548	(0,537)
region 4 dummy	0,316	(0,687)	0,308	(0,687)
non-white dummy	-1,287	(0,597)	-1,267	(0,597)
hispanic dummy	-1,403	(0,742)	-1,393	(0,742)
Inverse Mills Ratio	-5,717	(3,535)	-5,740	(3,534)
	Estimated parameters and standard deviation of wife's market labor supply			
constant	34,846	(9,265)	35,134	(9,264)
husband's wage	-0,346	(0,813)	-0,332	(0,812)
wife's wage	0,552	(1,221)	0,515	(1,221)
husband's wage squared	0,008	(0,016)	0,008	(0,016)
wife's wage square	0,008	(0,023)	0,008	(0,023)
cross product of wages	-0,017	(0,014)	-0,016	(0,014)
net expenditure	0,000	(0,001)	0,000	(0,001)
age	0,113	(0,233)	0,109	(0,233)
age squared	-0,002	(0,003)	-0,002	(0,003)
education	_	_	_	_
region 2 dummy	0,906	(0,554)	0,899	(0,554)
region 3 dummy	1,343	(0,471)	1,345	(0,471)
region 4 dummy	-0,262	(0,585)	-0,264	(0,585)
non-white dummy	-0,529	(0,571)	-0,524	(0,571)
hispanic dummy	-0,034	(0,699)	-0,043	(0,699)
Inverse Mills Ratio	2,962	(3,052)	2,947	(3,051)

Table 3: Estimations of the collective model of labor supply with and without domestic production: estimates obtained by the SUR method with accounting for sample selection

	Chiappori (1992)'s model		Chiappori (1997)'s model	
	Estimated parameters and standard deviation of husband's domestic labor supply			
constant	_	_	7,025	(8,450)
husband's wage	_	_	0,010	(0,034)
wife's wage	_	_	0,090	(0,028)
age	_	_	-0,113	(0,351)
age squared	_	_	0,003	(0,004)
education	_	_	-0,355	(0,229)
region 2 dummy	_	_	2,641	(1,027)
region 3 dummy	_	_	0,380	(1,000)
region 4 dummy	_	_	0,876	(1,152)
non-white dummy	_	_	-1,442	(1,081)
hispanic dummy	_	_	-1,335	(1,394)
week-end dummy	_	_	6,128	(0,690)
Inverse Mills Ratio	_	_	-1,232	(2,673)
	Estimated parameters and standard deviation of wife's domestic labor supply			
constant	_	_	25,243	(14,467)
husband's wage	_	_	0,090	(0,028)
wife's wage	_	_	-0,086	(0,045)
age	_	_	0,038	(0,449)
age squared	_	_	0,001	(0,006)
education	_	_	-1,231	(0,461)
region 2 dummy	_	_	-1,594	(1,202)
region 3 dummy	_	_	-0,884	(1,218)
region 4 dummy	_	_	-1,027	(1,308)
non-white dummy	_	_	-1,015	(1,280)
hispanic dummy	_	_	0,955	(1,583)
week-end dummy	_	_	6,234	(0,777)
Inverse Mills Ratio	_	_	-5,962	(5,712)
	Estimated parameters and standard deviation of husband's market labor supply			
constant	33,844	(3,164)	33,791	(3,164)
husband's wage	-0,056	(0,045)	-0,051	(0,045)
wife's wage	0,025	(0,051)	0,025	(0,051)
husband's wage squared	0,001	(0,001)	0,001	(0,001)
wife's wage square	0,001	(0,001)	0,001	(0,001)
cross product of wages	-0,001	(0,001)	-0,001	(0,001)
net expenditure	-0,001	(0,000)	-0,001	(0,000)
age	0,111	(0,127)	0,111	(0,127)
age squared	-0,001	(0,001)	-0,001	(0,001)
education	0,490	(0,103)	0,490	(0,103)
region 2 dummy	0,688	(0,390)	0,687	(0,390)
region 3 dummy	0,204	(0,368)	0,205	(0,368)
region 4 dummy	0,048	(0,427)	0,046	(0,427)
non-white dummy	-1,350	(0,317)	-1,349	(0,317)
hispanic dummy	-1,346	(0,449)	-1,342	(0,449)
Inverse Mills Ratio	0,521	(1,027)	0,519	(1,027)
	Estimated parameters and standard deviation of wife's market labor supply			
constant	29,092	(5,236)	29,125	(5,235)
husband's wage	-0,209	(0,047)	-0,206	(0,047)
wife's wage	0,241	(0,055)	0,239	(0,054)
husband's wage squared	0,001	(0,001)	0,000	(0,001)
wife's wage square	-0,006	(0,001)	-0,006	(0,001)
cross product of wages	0,006	(0,001)	0,006	(0,001)
net expenditure	0,000	(0,000)	0,000	(0,000)
age	0,168	(0,161)	0,167	(0,161)
age squared	-0,003	(0,002)	-0,003	(0,002)
education	0,557	(0,179)	0,555	(0,179)
region 2 dummy	0,644	(0,412)	0,644	(0,412)
region 3 dummy	1,370	(0,403)	1,372	(0,403)
region 4 dummy	0,062	(0,461)	0,064	(0,460)
non-white dummy	-0,180	(0,369)	-0,178	(0,369)
hispanic dummy	0,092	(0,523)	0,095	(0,523)
Inverse Mills Ratio	-0,492	(1,892)	-0,504	(1,892)

Table 4: Estimations of the collective model of labor supply with and without domestic production: estimates obtained by the SUR method without accounting for sample selection

	Chiappori (1992)'s model		Chiappori (1997)'s model	
	Estimated parameters and standard deviation of husband's domestic labor supply			
constant	–	–	6,559	(8,381)
husband's wage	–	–	0,011	(0,033)
wife's wage	–	–	0,089	(0,027)
age	–	–	-0,107	(0,350)
age squared	–	–	0,002	(0,004)
education	–	–	-0,341	(0,228)
region 2 dummy	–	–	2,628	(1,027)
region 3 dummy	–	–	0,279	(0,976)
region 4 dummy	–	–	0,817	(1,144)
non-white dummy	–	–	-1,497	(1,072)
hispanic dummy	–	–	-1,471	(1,363)
week-end dummy	–	–	6,123	(0,690)
Inverse Mills Ratio	–	–	–	–
	Estimated parameters and standard deviation of wife's domestic labor supply			
constant	–	–	14,284	(9,387)
husband's wage	–	–	0,089	(0,027)
wife's wage	–	–	-0,086	(0,045)
age	–	–	0,279	(0,385)
age squared	–	–	-0,002	(0,004)
education	–	–	-0,856	(0,282)
region 2 dummy	–	–	-1,515	(1,200)
region 3 dummy	–	–	-1,269	(1,160)
region 4 dummy	–	–	-1,221	(1,295)
non-white dummy	–	–	-1,521	(1,185)
hispanic dummy	–	–	0,396	(1,489)
week-end dummy	–	–	6,229	(0,777)
Inverse Mills Ratio	–	–	–	–
	Estimated parameters and standard deviation of husband's market labor supply			
constant	33,892	(3,155)	33,843	(3,154)
husband's wage	-0,057	(0,045)	-0,052	(0,045)
wife's wage	0,020	(0,050)	0,020	(0,050)
husband's wage squared	0,001	(0,001)	0,001	(0,001)
wife's wage square	0,001	(0,001)	0,001	(0,001)
cross product of wages	-0,001	(0,001)	-0,001	(0,001)
net expenditure	-0,001	(0,000)	-0,001	(0,000)
age	0,114	(0,127)	0,113	(0,127)
age squared	-0,001	(0,001)	-0,001	(0,001)
education	0,497	(0,102)	0,497	(0,102)
region 2 dummy	0,676	(0,389)	0,675	(0,389)
region 3 dummy	0,240	(0,361)	0,241	(0,361)
region 4 dummy	0,059	(0,426)	0,057	(0,426)
non-white dummy	-1,321	(0,312)	-1,321	(0,312)
hispanic dummy	-1,298	(0,440)	-1,294	(0,440)
Inverse Mills Ratio	–	–	–	–
	Estimated parameters and standard deviation of wife's market labor supply			
constant	27,969	(3,322)	28,076	(3,322)
husband's wage	0,209	(0,047)	-0,207	(0,047)
wife's wage	0,241	(0,054)	0,240	(0,054)
husband's wage squared	0,001	(0,001)	0,000	(0,001)
wife's wage square	0,006	(0,001)	-0,006	(0,001)
cross product of wages	0,006	(0,001)	0,006	(0,001)
net expenditure	0,000	(0,000)	0,000	(0,000)
age	0,194	(0,134)	0,194	(0,134)
age squared	-0,003	(0,002)	-0,003	(0,002)
education	0,598	(0,112)	0,113	(5,308)
region 2 dummy	0,644	(0,412)	0,644	(0,412)
region 3 dummy	1,338	(0,383)	1,339	(0,384)
region 4 dummy	0,037	(0,452)	0,038	(0,452)
non-white dummy	-0,226	(0,330)	-0,331	(0,680)
hispanic dummy	0,031	(0,473)	0,474	(0,069)
Inverse Mills Ratio	–	–	–	–

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.[17] 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, 1984). The Hispanic and non-white dummies are not significantly different from zero, but education is negative and significant for wives. The weekend days dummy is positive and large. In other words, spouses devote more time to household chores during weekend.

To obtain more precise results, we also consider the estimated parameters obtained by the SUR method without accounting for sample selection on Table 4. In general, standard deviations are moderately smaller, in particular for socio-demographic variables, but the results are not altered by the omission of the inverse of Mill's ratio from labor supply equations.

The main conclusion we can draw from the reduced-form estimations is that instruments are not sufficiently strong to provide precise estimations of the parameters. In what follows, we will focus on the estimates obtained by the SUR method (accounting for sample selection) which are a little more significant. In addition, the estimations given by this method are much more convincing in view of the past literature. However we must keep in mind the possible bias that may result from the endogeneity of wages rates.

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, (3)-(6), has been estimated without imposing the constraint $A_2 = B_2$

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

and, then, the test statistic has been computed as

$$t = \frac{A_2 - B_2}{\sqrt{\mathsf{var}(A_2) + \mathsf{var}(B_2) - 2\mathsf{cov}(A_2, B_2)}}$$

This statistic is asymptotically distributed as a standardized normal. For the SUR estimation taking into account selection, its value is equal to -0.357, then we do not reject the hypothesis of symmetry at usual levels. Moreover, data confirms that domestic labor supplies are independent from non labor income, as the theoretical model says. The reduced-form labor supply equations, (3)-(6), 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 0.748 and -0.861 for the husband's and the wife's equations, respectively.

5.2 The structural-form models

In this subsection we turn to the estimates of the structural parameters, obtained with the SUR method. These results are reported in Table 5 and are derived using the formulae previously given. Concerning the Marshallian labor supply equations, the estimates of Chiappori's (1992) model and those of Chiappori's (1997) model 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 the right-hand side of expressions (10g) (or (16g)) and (10h) (or (16h)) 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.[18] Be that as it may, the other parameters of the husband's income share are less precisely estimated and differ moderately for the two models we examine. 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 wage rate and wife's wage rate reduces the husband's income share by about fifteen dollars and twelve dollars, respectively. Such a reduction in the husband's share is plausible, as explained by Donni (2007), because the wife should benefit from the increase in husband's wage rate as well. Note indeed that an increase in the husband's wage rate implies an increase of the husband's welfare by thirty-seven units.

Overall, the results are similar for the model with domestic production. Nonetheless, the negative effect of the wife's wage rate on the husband's share (or the husband's welfare) is much more marked than in the model without domestic production. To be precise, the marginal effect of a one-dollar increase in the wife's wage rate reduces the husband's income share by about seventy four dollars, which is considerable. One explanation 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 in his utility, due to an increase in wife's wage rate is thus underestimated. On the contrary, in the collective model with domestic production, the welfare of husbands turns out to be more largely affected, as indicated by the marginal effects exhibited in Table 5, by the increase in wife's wage rate. Nevertheless, the standard deviations are excessively large so that it is not possible to draw definitive conclusions.

To sum up we can say that welfare measurement does not seem importantly affected by the omission of domestic activities in the collective model. The estimates of the parameters of the sharing rule are admittedly different for the two models, but standard deviations are large and these differences does not appear to be

[18] All the studies mentioned above suppose that net expediture has a linear effect on market labor supply. Other studies by Fortin and Lacroix (1997) and Donni et Moreau (2007) do not furnish precise estimation of the structural parameters.

Table 5: Estimations of the structural parameters of the model: estimates obtained by the SUR method with accounting for sample selection

	Chiappori (1992)'s model		Chiappori (1997)'s model	
	Estimated parameters and standard deviations of the husband's share of income			
husband's wage	-33,788	(31,043)	-26,255	(19,488)
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)
	Estimated parameters and standard deviations of the husband's Marshallian labor supply			
husband's wage	-0,104	(0,058)	-0,078	(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)
	Estimated parameters and standard deviations of the wife's Marshallian labor supply			
wife's wage	0,350	(0,236)	0,506	(0,338)
wife's wage squared	-0,004	(0,005)	-0,004	(0,004)
wife's income share	-0,006	(0,006)	-0,005	(0,004)
	Estimated marginal effects and standard deviations on husband's share			
husband's wage	-14,834	(13,731)	-6,305	(6,182)
wife's wage	-11,802	(24,738)	-74,314	(34,899)
net expenditure	0,923	(0,094)	0,909	(0,102)
	Estimated marginal effects and standard deviations on husband's welfare			
husband's wage	28,900	(13,731)	37,428	(6,182)
wife's wage	-11,802	(24,738)	-74,314	(34,899)
net expenditure	0,923	(0,094)	0,909	(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. The marginal utility of money is normalized to one.

significant. Similarly, estimations of the effect of wage rates and net expenditure on individual utilities are not very sensitive to the choice of the structural model (only the cross-effect of wage rates differs notably, but standard deviations remain large). Our conclusion contrasts with that of Rapoport, Sofer and Solaz (2010), who show that ignoring domestic production leads to biased estimates of the sharing rule. Actually, 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, so that distortions remain limited. Because the study of Rapoport, Sofer

and Solaz (2010) uses a different methodology and does not explicitly estimate domestic labor supply equations, it is difficult to continue the comparison, and explain the differences between these studies.

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 (Chiappori, 1992). This conclusion, however, must be balanced by the fact that the parameters are not estimated with a great precision (at least when wage rates are instrumented).

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:

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

where $\Psi = \Psi^1$ and $y + \Pi - \Psi = \Psi^2$. Then we calculate the derivatives of total labor supply functions with respect to the partner's wage and non-labor income, that is,

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

and

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

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

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

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

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

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

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 rule, that is,

$$\Psi_y = \frac{AB_y - Bw_2 - t^1_{w_2}}{A_{w_1} + AB_y - Bw_2 - A_yB},$$

and

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

□

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