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THE ESTIMATION OF PRICE ELASTICITIES AND THE VALUE OF TIME IN A
DOMESTIC PRODUCTION FRAMEWORK: AN APPLICATION USING FRENCH
MICRO-DATA

FRANÇOIS GARDES^a

This article uses an allocation of time framework following Becker, to propose a new method to estimate the opportunity cost of time and price elasticities at a micro level. As expected, the estimate of the value of time performed by matching the INSEE Family Budget and Time Use surveys is close to the minimum wage rate and positively correlated with household wages, incomes and relative incomes, as well as with the presence of children. Using this estimate, full prices are derived, allowing the computation of cross-section data of price elasticities, elasticities with respect to time use, as well as to the opportunity cost of time.

JEL Codes: C33, D1, D13, J22.

Keywords: Allocation of Time, Full Price, Opportunity Cost of Time, Price Elasticity, Time Elasticity.

INTRODUCTION

The goal of this article is to evaluate the value of time within the framework of domestic production, and to use this evaluation to estimate price elasticities on a cross-section dataset. Another novelty of this study is that I also estimate the elasticities of consumption with respect to changes in time use and the opportunity cost of time. These parameters have not yet been considered in the applied analysis of consumption. In order to estimate the opportunity cost of time for each household, I propose a modified version of Becker's allocation of time model, in which the value of time is not set equal to the household's wage rate. This allows proxies to be put forward for full prices, under alternative assumptions of the complementarity or substitution between monetary expenditures and time uses, which are then used in the estimation of price elasticities. The calculation of these full prices, under alternative assumptions of complementarity or substitution between time and money, is also new in the literature.

The estimation of price elasticities for large micro-data sets is indeed an important matter since it may provide more robust parameters than the estimation on macro time-series. It also provides the opportunity of comparing different sub-populations (young vs old people, rich vs poor, etc.), which is crucial for the micro-simulation of public policies, for the measurement of the welfare change associated with price variations and to the test theoretical assumptions (such as the integrability of demand functions).

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The contribution of this paper is thus: i) to propose a new method to evaluate the opportunity cost of time used in the domestic production (enabling the monetary value of this production to be measured); ii) to develop a new method in order to estimate price elasticities at a micro level; iii) to give estimates of the effects of changes in the value of time or the amount of time used in a domestic activity, over the monetary and time expenditures of the household, and iv) to offer the possibility of calculating the level of indirect utility depending on monetary expenditures and time-uses.

Section 1 presents the objective and the methods of the article. The next section provides a discussion of the difference between the wage rate and the opportunity cost of time and proposes a generalized Becker-type model of time allocation, in order to value time used in domestic activities. Section 3 gives two alternative empirical definitions of full prices while Section 4 presents the econometric specification of the demand system and the matching procedure of the French surveys. Section 5 discusses the resulting estimations of price and time elasticities using a French INSEE survey.

1. RATIONALE

Changes in time allocation are prominent during agents' life cycles as well as between small and large families. They are also linked to macroeconomic shocks, as shown during the recent Great Recession by Aguiar, Hurst, and Karabarbounis (2013) (see also Alpman and Gardes (2015) and the analysis of trends of time devoted to market work and leisure by Aguiar and Hurst (2007b)): aggregate market work fell by 7% in the US between 2008 and 2010, and 45% of these hours were reallocated to non-market work and child care¹. Considering time allocation together with consumption expenditures is thus crucial since both result in a consumption activity which differs from that suggested solely by monetary expenditures (see for instance the analysis of food consumption by the elderly by Aguiar and Hurst (2005)).

On the other hand, valuing time is a crucial issue in the domestic production framework since it allows the estimation of the monetary value of that production, which is "a central problem" according to Gronau (1977). The classical microeconomic model of the consumer introduced time only as a supplementary constraint, with the value of time being equal to the corresponding Lagrange multiplier, without any systematic testing of the theory in the empirical literature. As a consequence, the opportunity cost of time is commonly set equal to the wage rate, net of taxes in empirical analyses. Estimations here prove that it is much lower, while there is also much heterogeneity in the population: the opportunity cost of time increases with the presence of children, as well as with the household's net wage and its relative income (compared to a reference population).

Contemporary thinking about the value of time originates in Becker's model of time allocation (Becker, 1965), in which time is defined as the shadow price of the non-working use of time. The difficulties encountered in exchanging time between two individuals imply that no market price exists for time. Indeed, time can be indirectly exchanged through services given or sold by an individual to another. But some domestic tasks (such that caring for children) may be hard to substitute with services obtained on the market, or

¹Note that this allocation may also differs between men and women and thus depends on the family structure: Aguiar and Hurst (2007b) show for instance that the increasing trend of leisure time have been compensated by a decrease in market work for men, contrary to women who have diminished their domestic production hours.

through a direct relationship with another individual. The valuation of time must therefore be based on the substitution between time and monetary resources for one individual or within a family. When this value is calibrated as the official minimum wage rate, it supposes that this minimum wage is close to the market wage of market substitutes for domestic activities. In the second method, when time is supposed to be perfectly exchangeable between household's market and non-market activities, the opportunity cost of non-market (domestic) work is calibrated as the average expected wage rate (usually adjusted for income tax and the estimated numbers of working days and hours) for all individuals in the family. This assumption of perfect substitutability is highly disputable.

Curiously, it seems that Becker's home production theory has not been yet systematically applied to the practical estimation of the value of time and consequently of full income and full price elasticities, except in the literature on transportation costs. An exception is the estimation of the substitution between shopping time and expenditures by Aguiar and Hurst (2007b). They find an elasticity between price and the frequency of shopping trips that is between 7 and 10 percent. This allows the opportunity cost to be calculated at \$1.67 per hour (see Alpman and Gardes (2015)). While the opportunity cost derived from Aguiar and Hurst (2007a) is significantly smaller than our estimates for the United States (around \$8 per hour, see Alpman and Gardes (2015)) and for France (see Table I), its evolution with respect to age is similar to ours: the opportunity cost of time begins to decline when individuals reach 35-39 years old (Aguiar and Hurst, 2007b).

The estimation of the opportunity cost of time can be applied to the computation of full prices (summing the monetary unit price of a commodity and the time cost of the corresponding activity) and full income of the household (summing its monetary income and the monetary value of the time devoted by the household to home production or related chores). These two important concepts of Becker's model are used here in the estimation of a demand system on cross-sectional data. Indeed, price-elasticity estimates on macro time series are generally considered as not being robust to the specification of the demand system and to the estimation method. They suffer from aggregation biases and lack of information, because the stationarity conditions cannot be verified for long term series. Moreover, estimation from macro data gives no information on the change of price effects according to the individual characteristics such as the age or cohort of the family head, the family structure or its level of being. Indeed, the estimation of price demand effects for different sub-populations (young vs. old people, rich vs. poor, etc.) is important for the micro-simulation of public policies and the measurement of welfare changes associated with price variations.

Various methods have been proposed to estimate price elasticities on cross-section individual data, but all suffer from unrealistic assumptions or necessitate special datasets which are uncommon or reduced to food expenditures. Deaton (1988) proposed to compute price elasticities on cross-sectional micro-data using unit values (for surveys containing information on the quantities consumed and the value of expenditures). These unit values may incorporate a quality effect (expensive bread, for example, may have a higher quality) which is removed by comparing the unit prices with average local prices. This method has been applied essentially to food consumption, as the quantities consumed are rather difficult to measure for other items. Another possibility consists of making the assumption of a strong separability between consumptions (a hypothesis leading for instance to Stone's Linear Expenditure System) in order to obtain a relationship between price- and income-elasticities by the Frisch formula (Frisch, 1959). This separability as-

sumption is generally strongly rejected by the data. Another method uses arc-elasticity which can be computed by a difference-in-difference method between two periods characterized by large changes in prices (see Merrigan and Gardes (2014) for such an estimation of the price-elasticity for tobacco using a two-period panel). This method can be used only with a special panel contemporary to the large price changes. Finally, different prices indices can be computed using as weight the current budget shares of the individual consumer, as proposed originally by Stone and Lewbel. An application on French surveys by Ruiz (2006) shows that this method, apart from the obvious endogeneity which characterizes it and which implies discarding information on prices by instrumentation, gives rise to highly variable estimates of price elasticities, with some highly unrealistic values.

In empirical applications, when full prices are not calibrated at the net wage rate (which is the usual assumption), they are defined under very special and disputable hypotheses. For instance, in a paper on transportation costs, De Vany (1974) assumed that income and price elasticities of air travel depend linearly on the distance of travel. Recent papers by Jara-Diaz and Jorge (2017) are also characterized by such restrictive assumptions. The direct specification of a reduced form demand function over the monetary prices of market goods, the value of time and some income variable (either monetary income or full income) is highly disputable, since it mixes the effects of changes in the monetary and time components of the full price with the effect of the opportunity cost of time through the full income. Take for instance the recent article by Zieba (2009) which estimates the price elasticity of theatre tickets in Germany using a reduced form demand equation. The specification is double logarithmic and two different equations relate the theatre attendance per capita to the ticket price, the price of leisure and, either the household's disposable money income, or its full income. The time used for transportation and attendance is valued at the regional average market wage of the German population, multiplied by the proportion of households working in the labor market (an empirical proxy of the household's expected wage). The full-income sums the household's monetary disposable income and leisure time income. The elasticity over the price ticket is estimated at -0.28, while the full price elasticity culminates at -4.16 and the monetary and full income elasticities are respectively 1.16 and 5.65. The full-income and full price elasticities thus appear as being extremely high. In this specification with full income and full prices, the effect of a change in the opportunity cost for time is double: through the full price elasticity and the time component of the full income, which explain these implausible estimates².

2. A MODEL OF THE ALLOCATION OF TIME WITH AN ENDOGENOUS VALUE OF TIME

The opportunity cost of time is usually defined as the Lagrange multiplier of a time constraint: in such a model, households are supposed to maximize a direct utility depending on the time devoted to leisure T_d and on the quantities consumed x of a Hicksian composite good containing all market goods whose relative prices are constant across the population. Under perfect substitution between market and domestic labor, the ratio of the marginal utilities of time and market expenditure equals both the opportunity cost divided

²This can be shown by multiplying the full income elasticity by the ratio between the time component and the full income (0.64 in average as measured on our French statistics, see Table II - note that a correct specification may use instead the marginal effect of the time component of the full income): the sum of the income and price effects of a change in the opportunity cost for time amounts to -0.53, which is close to the ticket price elasticity.

by the price of the market good and the wage rate divided by the same price. The opportunity cost of time is thus supposed to be equal to the net wage rate. This is discussed in the first sub-section.

2.1. *Discussion on the difference between the wage rate and the opportunity cost of time*

All direct surveys asking individuals to reveal their opportunity cost of time (OCT) give values which are much lower than their wage rate net of taxes, by at least 50%. For instance, the estimate derived by Aguiar and Hurst (2007a) looking at consumers' market behavior (time spent compared to expenditures) are around \$1.5 per hour, a probable under-estimate of the OCT for other activities. Various reasons may explain a difference between the opportunity cost of time and the wage rate: Whenever the two adults of a couple are not employed in the labor market, the household's OCT linked to what the income opportunity of employment could be, either the minimum of the OCT of the non-working adult and the wage rate of the employed partner, or the average of the estimated wage rate of the non-working adult and the wage rate of the employed partner (assuming the substitutability of the incomes of both partners). The first case generally gives a smaller evaluation compared to the second case. All expenses due to working in the labor market (clothes, transportation costs, investment in human capital, etc.) must be deduced from the wage rate, as well as the marginal income tax (which rises with income). For a similar task, the productivity of the same individual in the labor market or at home may be larger in the labor market, because of an adapted environment (computers, etc.) and human capital (the investment being paid by the employer). This implies a higher wage rate. As noted by Folbre, "most people lack the resources and the skills to successfully substitute home production to market purchased goods": in this case, people prefer to obtain a net wage (i.e. less taxes) by working in the market that is greater than their productivity at home, and then buy substitute goods or services in the market. For individuals with low productivity in the labor market, their wage rate and their OCT should be equal to the official minimum wage rate. For other individuals with a higher productivity, the estimations show that the elasticity of the opportunity cost of time with respect to the wage rate is smaller than 1, so that on average the OCT would be smaller in the population than the average wage rate. In France for instance, the estimated OCT is around 50% of the individual wage rate, and its ratio seems to diminish with the average level of income of a country (see a comparison between France, Canada, Ecuador and Guatemala in Canelas, Gardes, Merrigan, and Salazar (2019)). The disutility linked to working in the market may be greater than the disutility of domestic work, because of the freedom implied by working at home and frequent joint production (e.g., discussions between partners while preparing meals, etc.). Constraints in the labor market impart a virtual cost corresponding to the Lagrange multiplier of each particular constraint. Such constraints occur, for instance, if actual working time is longer than the minimum imposed by the firm, or indeed if working time cannot exceed a legal maximum. Finally, the opportunity cost of time may differ from the market wage, not only because of the disutility attached to market labor compared to home production, but also because of the possibility of joint production which characterizes the latter (see the discussion of this point in Gronau and Hamermesh (2006), and Apps and Rees (2009), and a detailed analysis of this difference in sub-Section 1.2).

The model put forward in Section 1.2 is based on the estimation for each household of its opportunity cost of time by means of the first order conditions in a domestic production framework. It thus differs from the methods used for instance in transport economics,

which are based on the calculation of the Lagrange multiplier corresponding to a time constraint, which necessitates specific identification constraints (see for instance Jara-Díaz and Jorge (2017), Rosales-Salas and Jara-Díaz (2017) and DeSerpa (1971)). Here, a unique utility function is assumed for households, so that future research could analyze collective decisions and the allocation of goods and time within the family. As an example of an analysis in terms of collective decisions, Couprie and Ferrant (2015) test the separability between consumption and time use (separability is rejected for French statistics for couples but not for singles), and they analyze economies of scale, equivalence scales and welfare comparisons based on time use statistics. Intra-household distribution and welfare comparisons are also examined in recent interesting papers by Bargain and Donni (see for instance Bargain, Donni, and Kwenda (2014)). Note that Bargain et al. conclude that “imposing the restriction that parents behave as a single unit leads to similar results” compared to their collective approach.

2.2. A Beckerian model of the allocation of time with an endogenous value of time

In the Becker’s original home production theory, the same opportunity cost of time applies for the time factor of the home production and on the labor market. I now turn to a model where the value of time in domestic production can differ from the household’s wage rate and where the agent maximizes a direct utility function depending on the quantities of a set of activities given by the domestic production functions. Becker (1965) considers a set of final goods (named also here activities) the quantities of which z_i , $i=1$ to I , enter the direct utility of the consumer $u(z_1, z_2, z_3, \dots, z_I)$. In order to simplify the analysis, Becker states that a separate activity i produces the final good i in quantity z_i using a unique market good³ in quantity x_i and time t_i together with all other (socio-economic) resources or characteristics of the household in a vector G : $z_i = f(x_i, t_i; G)$. The consumer’s program writes:

$$\max_z u(z_1, z_2, z_3, \dots, z_I)$$

such that $z_i = f(x_i, t_i; G)$ under the constraints on resources

$$(1) \quad \sum_i p_i x_i = y \quad \text{and} \quad \sum_i t_i + t_w = T$$

with $y = wt_w + y_0$ the monetary income which sums the labor income with other incomes y_0 , t_w the labor time on the market and T the total disposable time for one period. In the consumer program below, the domestic production functions will be written in terms of monetary expenditures ($m_i = p_i x_i$) instead of the quantity consumed since generally the latter is not observed in the Family Budget surveys.

In order to analyze that more complex decision model, I assume a Cobb-Douglas structure both for the utility and the domestic production functions of the final goods (which correspond to activities such as eating, transportation, housing, clothing or leisure activi-

³In case multiple market goods are used in activity i , a generalization to a bundle of market goods used to produce the activity can be performed by defining an aggregate commodity of the market goods corresponding to this activity. The monetary price p_i will be defined in this case as a price index for this aggregate, coherent with the monetary budget constraint.

ties). Note that all the parameters will be estimated locally (i.e. for each household in the dataset), so that this specification just assumes additive separability of the utility⁴ and, for each household, the constancy, in a neighborhood of its equilibrium point, of the elasticities γ_i of the domestic productions in the utility, and the elasticities α_i and β_i of the two factors in the production functions. The optimization program is (all variables correspond to a household h which index is omitted in the equations):

$$(2) \quad \max_{m_i, t_i} u(Z) = \Pi_i a_i z_i^{\gamma_i} \text{ with } z_i = b_i m_i^{\alpha_i} t_i^{\beta_i}$$

under the full income constraint:

$$(3) \quad \sum_i (m_i + \omega t_i) = w t_w + \omega (T - t_w) + y_0$$

The full income y^f is the maximum monetary income which could be earned when working during all disposable time T (excluding sleeping time, although, as remarked by Aguiar and Hurst (2007b) sleeping time is in fact a choice variable over which individuals optimize. Sleeping time is generally excluded from domestic and leisure time in the time use literature), at the market wage rate net of taxes w with y_0 designing other monetary incomes:

$$y^f = wT + y_0 = y + \omega(T - t_w) = y + \omega \sum_i t_i$$

It is assumed here that the agent's opportunity cost ω differs from her net wage, so that the full budget constraint writes:

$$\sum_i (p_i + \omega t_i) = y^f + (\omega - w)(T - t_w) = y^f + (\omega - w) \sum_i t_i$$

In this formula, the full income is thus corrected by the difference between the market (w) and the personal valuation (ω) of the total domestic time $\sum_i t_i$: the agent subtracts the transaction cost between her leisure and market labor opportunity cost of time from her full income (this correction applies when the market labor supply t_w is predetermined, which defines the monetary income). This full budget constraint differs from the usual one whereby leisure or consumption time is valued by the agent's net market wage rate. This particularity allows a new method to be proposed to estimate the agent's opportunity cost of time.

Note that $T - t_w = \sum_i t_i = T_d$ and that both the market wage and the shadow wage (i.e. the opportunity cost of time ω^5) appear in the budget equation: the shadow wage

⁴Separability assumptions are highly disputable and generally empirically rejected (see our results based on the comparison between income and price elasticities in section 4.2). Nevertheless, it could be justified by the semi-aggregate nature of commodities, which diminishes the substitutability between commodities compared to the substitutability between similar goods within the same commodity.

⁵Supposed to be constant among all domestic activities. Child care is sometimes considered as more enjoyable than other domestic activities because of it is rationed. I thus assume that there exists no corner optimum in time allocation among domestic activities.

corresponds to the valuation of time in domestic production, and it is supposed to differ from the market wage w (see the discussion in the sub-next section)⁶. Note that prices p_i enter the utility function via $m_i = p_i x_i$ (instead of a specification of utility over quantities x_i) but the monetary prices are supposed to be the same for all households (since no direct information on prices per household is available in the dataset) so that this specification corresponds to a utility depending on quantities.

This specification supposes that market work is exogenous (it is in fact the residual after domestic times have been subtracted from disposable time, supposed to be given as total time less necessary time for sleeping). That corresponds to the assumption that households follow a two-stage budgeting approach where market working time does not affect monetary expenditures and domestic times⁷. This assumption is natural if the market time is fixed at an official amount as is the case in France (35 hours a week), but it can be discussed for all individual able to work supplementary hours or less than the official limit. It can indeed be assumed that while hours may be more regulated in fulltime jobs, part-time employment exists also in France which may be quite relevant in the decision between child care expenses and market work, for example. This is a limitation of the paper. Integrating the choice of market work would be possible but necessitates incorporating some variables which are not present in our dataset (but disposable in surveys on labor supply, which could be matched with our dataset).

2.3. Resolution of the model

In order to estimate the opportunity cost for time, the utility function is re-written:

(4)

$$u(Z) = \prod_i a_i z_i^{\gamma_i} = \prod_i a_i b_i^{\gamma_i} \left[\prod_i m_i^{\frac{\alpha_i \gamma_i}{\sum \alpha_i \gamma_i}} \right]^{\sum \alpha_i \gamma_i} \left[\prod_i t_i^{\frac{\beta_i \gamma_i}{\sum \beta_i \gamma_i}} \right]^{\sum \beta_i \gamma_i} = a m' \sum \alpha_i \gamma_i t' \sum \beta_i \gamma_i$$

with m' and t' the geometric weighted means of the monetary and time inputs with weights $\frac{\alpha_i \gamma_i}{\sum \alpha_i \gamma_i}$ and $\frac{\beta_i \gamma_i}{\sum \beta_i \gamma_i}$. Deriving the utility over monetary income y and total leisure and domestic production time T_d gives the opportunity cost of time:

$$(5) \quad \omega = \frac{\frac{\partial u}{\partial T_d}}{\frac{\partial u}{\partial y}} = \frac{\frac{\partial u}{\partial t'} \cdot \frac{\partial t'}{\partial T_d}}{\frac{\partial u}{\partial m'} \cdot \frac{\partial m'}{\partial y}} = \frac{m' \sum_i \beta_i \gamma_i}{t' \sum_i \alpha_i \gamma_i} \cdot \frac{\frac{\partial t'}{\partial T_d}}{\frac{\partial m'}{\partial y}} = \frac{\sum_i \beta_i \gamma_i}{\sum_i \alpha_i \gamma_i} \cdot \frac{y El_{t'/T_d}}{T_d El_{m'/y}}$$

The ratio of the time and income elasticities: $\frac{El_{t'/T_d}}{El_{m'/y}}$ is estimated on our data as smaller but close to one. The value of time is thus proportional to the ratio of an index of monetary expenditures over time use⁸. Note that all parameters of the utility function are estimated

⁶Also, the household average opportunity cost of time may differ from the head's wage rate for complex family structures.

⁷However, as noted by a referee, Browning and Meghir (1991) demonstrated important non separabilities between labor supply and consumption choices that vary across goods.

⁸Note a similar proportionality in the first order condition for minimizing the cost of shopping intensity in Aguiar and Hurst model: using their equation 2 (Aguiar and Hurst (2007a), page 1536), the opportunity

locally by the first order conditions, so that the household's welfare depends both on the set of parameters (α, β, γ) and on its monetary and time expenditures m_i and t_i ⁹.

The Cobb-Douglas specification of the utility and the domestic production functions are necessary in order to be able to write the utility in terms of geometric means of expenditures and time uses. As these functions are estimated locally, they can correspond to any global specification for a static comparison between households (the Cobb-Douglas specification concerns only small deviations from the household's equilibrium). As noted by a referee to this paper, that Cobb-Douglas structure rules out complete specialisation (in case where some commodity consumption is fully outsourced on the market), in the sense that the monetary or time input to each domestic production must be positive in order to insure a positive utility. But our commodities are defined broadly and each contains a large part of all consumptions, so that the expenditure and time inputs are always positive on our dataset (even on data containing both expenditures and time use, the inputs are positive for all households for such broad commodities: see for example an application of the model for such surveys from Burkina Faso in Gardes and Thiombiano (2017)).

2.4. Estimation of the opportunity cost of time

In order to calculate the parameters of the utility and domestic production functions, I consider the substitutions which are possible, first between time and monetary resources for the production of some activity, second between monetary expenditures (or equivalently time expenditures) concerning two different activities. First, the substitution between time and money in the domestic production function of activity i generates the first order conditions:

$$\frac{\frac{\partial u}{\partial t_i}}{\frac{\partial u}{\partial m_i}} \omega \Rightarrow \frac{\alpha_i}{\beta_i} = \frac{m_i}{\omega t_i}$$

which implies:

$$(6) \quad \alpha_i = \frac{m_i}{m_i + \omega t_i}, \beta_i = \frac{\omega t_i}{m_i + \omega t_i}$$

under the constraint of a constant economy of scale for each production function: $\alpha_i + \beta_i = 1$ ¹⁰. It is also assumed that all marginal productivities are positive: $\alpha_i, \beta_i, \gamma_i > 0$ and the utility is normalized with the constraint $\sum \gamma_i = 1$ (no economy of scale in the utility. Note that the estimation of these coefficients without that restriction gives a sum close to 1 up to 0.01, see Table V in Appendix).

Consider now the substitution between times t_i and t_j in the domestic production of two different final goods i and j : this substitution implies another condition between the

cost of time can be written as the negative of the product of the elasticity of price with respect to shopping time cross the ratio of monetary over time expenditures.

⁹This direct utility can be used to estimate welfare calculations, which generalize usual welfare calculations based solely on wages and monetary expenditures (see the discussion by Aguiar and Hurst (2007a) and an application in Canelas, Gardes, and Salazar (2013)).

¹⁰This restriction is necessary for the identification of the model, which could also be obtained fixing the sum of each couple (α_i, β_i) to some pre-determined value.

parameters of the domestic production functions and the utility function:

$$(7) \quad \frac{\gamma_i}{\gamma_j} = \frac{\beta_j t_i}{\beta_i t_j} = \frac{\alpha_j m_i}{\alpha_i m_j}$$

so that:

$$(8) \quad \gamma_i = \gamma_1 \frac{m_i}{m_1} \cdot \frac{\alpha_1}{\alpha_i}$$

for all $i \neq 1$.

All other substitutions between monetary and time resources devoted to different activities can be derived from (7) and (8).

In order to estimate these parameters, a possible method consists in the calibration of the opportunity cost of time in a first stage, for instance at the minimum wage rate which is constant over the population. Equations (6) thus give an estimate of α_i and β_i for each household, which gives γ_i by equation (7). In the second step, an estimate of the opportunity cost of time ω is given by equation (5) which allows the computation of the individual values of the parameters α, β, γ for each household using equations (6) and (8). These values enter equation (5) to give for each household the second step estimate of ω . The estimations on the French data as well as simulations¹¹ tend to show that this procedure may not converge rapidly to the true value of the opportunity cost of time.

Another method can be based on equations (6) and (8) which imply for all activities i, j :

$$(9) \quad m_i \gamma_j = m_j \gamma_i + \omega \gamma_i t_j - \omega \gamma_j t_i$$

This could be estimated as a system of $\frac{n(n-1)}{2}$ independent equations, calibrating γ_j at the average full budget share for one good¹² or as a system of $\frac{(n-1)(n-2)}{2}$ equations under the homogeneity constraint of the utility function: $\sum \gamma_i = 1$. In this system, the opportunity cost of time is over-identified, as well as all $\gamma_j, j > 1$ ¹³. We can also sum equations (9) over j with $\sum \gamma_j = 1$ to obtain $(n-1)$ independent equations (with no loss of information):

$$(10) \quad m_i = \gamma_i(m + \omega T) - \omega t_i, \quad i = 1, \dots, n$$

This system of equations can be estimated for the whole population, which gives a unique estimate of ω for all households¹⁴. The estimation without constraints (with different OCT ω_i for each commodity and no additivity constraint on coefficients γ_i) shows

¹¹Performed by J. Boelaert and P. Merrigan.

¹²Note that taking together equations 7, 8 and 9 to calculate the value of ω gives rise to a highly non-linear equation in γ_i and ω which cannot be solved algebraically.

¹³Note that an estimation of this system of equation without constraint on the set of coefficients γ_i gives estimates the sum of which is close (up to 5%) to 1. On the contrary, estimating without the non-linear structure of the system of equations over the OCT and the γ , gives different estimates of the OCT, which shows that these constraints must be imposed in the estimation.

¹⁴The opportunity cost of time ω is over-identified in this system, which can be tested: a test for proportionality between equations shows that the structure of the system is not automatically verified in an unconstrained estimation (note that the large number of observations leaves no room for another result).

that the absence of economies of scale in the utility ($\sum \gamma_i = 1$) is verified while the differentiation of the OCT gives poor estimates (see Table V). This is due to the fact that the true model with specific OCT per commodity does not correspond to a specification (10) with just different OCT for each equation (the estimation of this model on this dataset gives estimates of specific OCT all positive, except one not significant small negative value).

The estimation can also be performed on sub-populations or by a non-parametric local regression, which affords a set of estimates over the population. The resulting estimates of the opportunity cost of time ω and the parameters γ_j of the utility function are then used through equations (8) and (9) to calculate α , β and γ for each household. Finally, these estimates of parameters α , β and γ are used to estimate the opportunity cost of time $\omega(h)$ for each household h in the population by equation (5). A generalization of the model with several different opportunity costs of domestic activities is possible defining T and Y as time and monetary resources for a subset of activities and separating this subset from their complementary use for other activities in the utility. This gives rise to a system of equations which differ from the definition of the opportunity cost of time in equation (9). The test of these differentiated OCT is left for a future research.

3. EMPIRICAL DEFINITION OF THE FULL PRICES

3.1. Full prices under substitutability assumption

Following Gronau (1977)¹⁵ the full expenditure can be written as the sum of its monetary and time components:

$$(11) \quad p_i^{f1} z_i = p_i x_i + \omega t_i$$

with π and p the full and the monetary prices corresponding to the quantities z and x of the activity and of the corresponding market good, for activity i (note that prices and the opportunity cost of time depend on household and time, which indices are removed).

The full price is the derivative of the full expenditure over z , which writes for the Cobb-Douglas specification of the domestic production functions:

$$(12) \quad p_i^{f1} = p_i \frac{\partial x_i}{\partial z_i} + \omega \frac{\partial t_i}{\partial z_i}$$

The optimization program (4) gives rise to the first order condition: $\frac{t_i}{x_i} = \frac{p_i}{\omega} \cdot \frac{\beta_i}{\alpha_i}$ corresponding to equations (7) in section 1 (note that α and β depend on the household). Writing the quantity of the activity z_i in terms, either of t or x , gives:

$$(13) \quad t_i = \frac{1}{a_i} z_i \left(\frac{p_i \beta_i}{\alpha_i} \right)^{\alpha_i} \text{ and } x_i = \frac{1}{a_i} z_i \left(\frac{\omega \alpha_i}{p_i \beta_i} \right)^{\beta_i}$$

So that the full price becomes:

$$(14) \quad p_i^{f1} = \frac{1}{a_i} p_i^{\alpha_i} \omega^{\beta_i} \left\{ \left(\frac{\beta_i}{\alpha_i} \right)^{\alpha_i} + \left(\frac{\alpha_i}{\beta_i} \right)^{\beta_i} \right\}$$

¹⁵Suggested by Anil Alpman (see Alpman and Gardes (2015)).

This derivation of ω, α and β at the individual level allows identifying the full price for each household (a_i being supposed constant across the population).

3.2. Full prices under complementarity assumption

Becker's full price for one unit of activity i can be written: $p_i^{f2} = p_i + \omega\tau_i$ with τ_i the time use necessary to produce one unit of the activity i . Suppose (as in Becker's model) that a Leontief technology allows the quantities of the two factors to be proportional to the activity:

$$(15) \quad x_i = \xi_i z_i, t_i = \theta_i z_i$$

so that: $t_i = \tau x_{ii} \tau_i = \frac{\theta_i}{\xi_i}$.

This case corresponds to an assumption of complementarity between the two factors in the domestic technology, which allows calculating a proxy π for the full price of activity i by the ratio of full expenditure over its monetary component:

$$(16) \quad \pi_i = \frac{(p_i + \omega\tau_i) x_i}{p_i x_i} = \frac{p_i + \omega\tau_i}{p_i} = 1 + \frac{\omega\tau_i}{p_i} = \frac{1}{p_i} p_i^{f2}$$

Note that under the assumption of a common monetary price p_i for all households in a survey made in period t , this ratio contains all the information on the differences of full prices between households deriving from their opportunity cost for time ω and the home production technology represented by the coefficient of production τ_i . If the monetary price p_i changes between households or periods, the full price can be computed as the product of this proxy π_i with p_i : $p_i^{f2} = p_i \pi_i$. With these definitions, it is possible to measure the full prices, observing only monetary and full expenditures.

The first definition of prices corresponds to a complete substitution between the two factors in the model (which is used in section 1 to estimate the opportunity cost of time), since the Cobb-Douglas domestic production functions are characterized by a unitary elasticity of substitution between the two factors. It relies on the estimation of three parameters: α, β and ω . On the other hand, the second definition supposes no substitution between the two domestic production factors but it may give a more robust measure of the full prices since it depends only on the estimation of the households' opportunity cost for time ω . Both definitions of the full prices will be used in the estimation. However, there exists a simple relation between these two definitions of the full prices. Using equations (8) we obtain:

$$(17) \quad p_i^{f1} = \frac{1}{a_i} \left(\frac{m_i}{\omega t_i} \right)^{\beta_i} \left\{ 1 + \frac{\omega t_i}{p_i} \right\}$$

So that their logarithmic transforms differ only by $\beta_i \log \left(\frac{m_i}{t_i} \right)$ on a cross-section:

$$(18) \quad \log \left(p_i^{f1} \right) = \text{constant} + \beta_i \log \left(\frac{m_i}{t_i} \right) + \log \pi_i$$

With prices p_i set to one.

Two hypotheses were necessary to derive full prices from monetary and time expenditures: first, the domestic production functions are supposed to be Leontief functions

with constant production coefficients (for Becker's prices) or Cobb-Douglas functions (for Gronau's prices); second no joint production exists, which may be more easily verified for broad categories of activities such as housing and food¹⁶.

3.3. *An estimation of the elasticity of substitution between time and monetary resources*

In order to assess the degree of substitutability between the two factors, money and time, of the production function, I estimate of the elasticity of substitution between them for each commodity (see Canelas, Gardes, Merrigan, and Salazar (2019) , for details and a comparison with other countries). The specification proposed in Hamermesh (2008) is used, assuming a constant elasticity of substitution between time and money inputs in a household production function:

$$\log \left(\frac{m_i}{t_i} \right) = \alpha_i + \sum_i \log (\omega) + \varepsilon_i.$$

The estimation is made using, first the average household's wage rate, second the estimated opportunity cost of time, as the relative price ω of monetary and time resources. All the elasticities of substitution reported in Table I are positive and significant. The necessity goods, such as eating and housing, have the lowest elasticities, which is conform to Hamermesh's estimate for eating in the U.S. Thus, inputs of necessity goods are rather complementary since a minimum amount of money and time are both necessary to produce them and cannot be substituted entirely one for the other, while other commodities are rather substitutes. This justifies estimating price elasticities for both cases¹⁷.

4. ECONOMETRIC METHODOLOGY AND DATASET

4.1. *Econometric methodology*

I estimate on the full values of expenditures and prices¹⁸ a complete demand system based on the Almost Ideal specification under homogeneity and symmetry restrictions on price elasticities¹⁹. As has been remarked before, this flexible specification does not contradict the Cobb-Douglas specifications chosen in section 1 to estimate the opportunity cost of time: considering the Pig-log cost function corresponding to the Almost Ideal

¹⁶A joint production of two different activities (made by the same individual in the same time, for instance smoking and drinking) would create a correlation between these activities. Grouping the two activities into a broader one (food, alcohol and tobacco) suppresses the problem.

¹⁷The definition of an intermediary concept of full prices under a partial substitution between the two factors is left for a future research.

¹⁸An alternative consists in estimating together a system of equation related to monetary expenditures with a system related to time uses. It is straightforward (Alpman (2016) ; see also Alpman and Gardes (2017)) that introducing the total domestic time use in the expenditure demand functions allows to satisfy all the theoretical constraints (additivity and the symmetry of price effects) for both systems. This specification provides the elasticities of consumptions over both resources (income and time) and the full price effects over monetary expenditures and time uses (which differ from the coefficients of our system on full expenditures and prices).

¹⁹A Quadratic specification (QUAIDS) gives similar estimates of the price parameters but does not converge under the two theoretic restrictions (homogeneity and symmetry). Other versions of the demand system have been estimated using for instance the monetary budget shares instead of the full ones or monetary total expenditure instead of their full version (see Table V).

TABLE I
ELASTICITY OF SUBSTITUTION

Commodity Groups	Over Wage rate	Over Estimated OC of Time
Eating	0.366	0.415
	(0.021)	(0.032)
Housing	0.521	0.849
	(0.023)	(0.034)
Transportation	0.399	0.287
	(0.021)	(0.032)
Clothing	1.345	1.038
	(0.051)	(0.067)
Leisure	0.958	1.272
	(0.032)	(0.047)
Other	0.558	0.651
	(0.024)	(0.037)
All but Food	0.512	0.584
	(0.015)	(0.023)
Food*	0.281	0.276
	(0.021)	(0.032)
Number of observations	8424	8424

Notes: Bootstrapped standard errors, 1200 replications.
* Estimation in a system of two expenditures, with all expenditures other than food grouped. Opportunity cost of time estimated by cell using equation 11 (see Table III).

specification, any income or price derivative of the demand function corresponding to this form can be recovered locally by our Cobb-Douglas direct utility model the parameters of which are estimated locally, i.e. for each household.

In this specification both the endogenous variables (the full budget shares) and the exogenous variables (the full income and the full prices) depend on the estimation of the opportunity cost of time, which may imply endogeneity biases. In order to take care of this possibility, the full income has been instrumented and the budget shares have been computed with a different valuation of time (by the minimum wage). Other versions of the demand system have been estimated using for instance the monetary budget shares instead of the full ones or monetary total expenditure instead of their full version. These different specifications give close estimates of the price elasticities, as shown in the appendix (Table VI).

Another problem concerns the endogenous quality effects incorporated in the full prices). Indeed, the quality of final goods can be supposed to increase with the household's productivity (possibly linked to its value of time through its correlation with the household's average wage rate) and the time spent for this activity, which are both associated with the level of the two alternative measures of the full prices. These quality effects are corrected by a procedure inspired by Deaton's method (Deaton (1988) : see Appendix A).

Finally, the variances are corrected for generated regressors (the full prices) by an original bootstrap procedure. Details are provided in Appendix A.

Using full price elasticities $E_{\pi_i^{GB}}$, the elasticities over the own-monetary price E_{p_i} (which could be named input goods-elasticities), over the time used for the consumption

activity E_{t_i} and over the opportunity cost of time E_ω are easily recovered²⁰ :

$$(19) \quad E_{\pi_i^{GB}} = E_{\pi_i}^{GB} \frac{p_i}{\pi_i^B} = E_{\pi_i^{GB}} \frac{p_i x_i}{p_i x_i + \omega t_i}$$

$$(20) \quad E_{t_i} = E_{\pi_i^{GB}} \frac{\omega t_i}{\pi_i^B} = E_{\pi_i^{GB}} \frac{\omega t_i}{p_i x_i + \omega t_i}$$

$$(21) \quad E_\omega = \sum_j E_{\pi_j^{GB}} \frac{\omega t_j}{p_j x_j + \omega t_j}$$

4.2. Dataset

I use a French dataset from INSEE which combines at the individual level the monetary and time expenditures into a common, unique goods and services consumption structure by a statistical match of the information contained in two surveys: the Family Expenditure Survey (FES, INSEE BDF 2001) and the Family Time Budget (FTB, INSEE BDT 1999). I define 8 types of activities or time use types compatible with the available data both from FES and BDT: Eating and cooking time (FTB) and food consumption (FES), cleaning and home maintenance and dwelling expenditures (including imputed rent), clothing maintenance and clothing expenditures, education time and education expenditures, health care time and health expenditures, leisure time and leisure expenditures, transport time and transport expenditures, miscellaneous time use and miscellaneous goods and services.

Time uses for all selected activities are regressed on the households' characteristics for all observation units in FTB survey and these estimations serve to predict the time spent on these activities in the corresponding units in the FES survey. A matching of the Consumer Expenditure and the American Time use surveys using various methods, including Rubin's Multiple Imputation method Rubin (1986)²¹, shows that simple matching by regression gives similar estimates: Alpman (2016) compares regression based imputation with Rubin's multiple imputation for simulated data and shows that the later furnishes imputed data which are close to the original dataset. In Alpman and Gardes (2017), we use a survey containing both monetary expenditures and time uses for three final goods (Food, Domestic Activities and Other) and check that Rubin's procedure gives imputed values of time uses close to the true values. It may also be noted that the estimation of a demand system on full expenditures gives close results using a simple imputation by regression compared to the Rubin's matching procedure and to the estimation on the true values of expenditures and time uses.

Using for instance the proxy π_i of Becker's full prices and the opportunity cost estimated on 76 sub-populations by equation (11), the full expenditures can be compared

²⁰Similar formulas can be written for cross-price elasticities, see for instance De Vany (1974) (remark an error in his formulas which has been corrected here).

²¹Rubin's procedure allows imputing expenditures allocated to activity i as a function of time allocated to i and of the control variables, assuming a partial correlation value between expenditures and time allocated to activity i given the control variables. This correlation must be calibrated. The simple regression method corresponds to a zero correlation.

to the monetary and time expenditures (see Table II): their structure differ significantly, especially as far as dwelling and leisure expenditures are concerned. They are also quite different between different family types. The presence of children increases the ratio between monetary and time expenditures, especially for food, leisure and transport. These differences across households justify the local estimation of the parameters of the domestic production model.

TABLE II
MONEY, TIME AND FULL EXPENDITURE PATTERNS (ALL HOUSEHOLDS, SINGLES AND COUPLES)

	Monetary budget share	Time budget share	Full expenditure budget share	yearly monetary expenditure (euros)	full expenditure (money+ time value*) (euros)	Ratio of monetary exp. over time value	Ratio of monetary exp. over time value	Ratio of monetary exp. over time value	Ratio of monetary exp. over time value
	All households							2 Adults, no child	2 Adults with children
							Singles		
Eating	0,18	0,278	0,227	5102	16081	0,4246	0,43	0,35	0,46
Dwelling	0,331	0,11	0,203	9399	14412	1,6687	2,52	1,29	1,84
Clothing	0,067	0,032	0,041	1910	2924	1,2188	1,12	0,81	1,61
Transport	0,148	0,107	0,119	4197	8410	0,851,00	0,63	0,76	0,99
Leisure	0,166	0,382	0,288	4706	20452	0,2730	0,24	0,18	0,36
Other	0,107	0,07	0,122	3044	8626	0,861,55	0,83	0,91	0,75
TOTAL	1	1	1	28358	70905	0,6349	0,67	0,51	0,59

*valuation of time expenditures by the opportunity cost of time estimated on data grouped by cells (Table I).

TABLE III
ESTIMATES OF THE VALUE OF TIME ω

Method	Formula	ω	$\frac{\omega}{w}$	$\frac{\omega}{w^{min}}$	Min ω	Max ω
By cell	Equation (11)	6.03	0.63	0.87	1.82	11.33
s.e.		(2.14)				
Individual data	Equation (7)	5.00	0.52	0.73	0.02	483.53
s.e.		(6.05)				

By cell: equation (11) estimated on grouped data (76 cells defined by age groups, income per UC and 4 family structures: singles, couples without children, couples with children, more than 2 adults).
Individual data: in equations (7) the opportunity cost is calibrated at the value obtained for data grouped by cell. Eleven negative values not reported.
 w =average household's wage rate; w^{min} =minimum wage rate in 2000 (4.97 euros, which amount to 72% of the average wage rate).

“Income inequality” (comprising material and time resources) between households differs according to the monetary or full definition of income. The standard error of logarithmic total expenditure (per unit of consumption) is used as the inequality index (Table VII in Appendix). For the whole population, the inequality is smaller (by 18%) for full expenditure, a result which is approximatively reproduced for sub-populations P2, P3 and P4. For young singles (P1), the inequality is also smaller for full expenditure, but by a much larger amount. These figures are confirmed by the more precise analysis performed on the same dataset by Gardes and Starzec (2017).

Full prices depend on the opportunity cost of time and on the amount of time τ_i consecrated to each activity. Their variation (see Table VIII in Appendix) is quite large across the population (for instance, the full price for transport under substitutability varies from 1.003 to 6.66, with a mean 1.94 and a standard error 0.54). The OCT and τ_i may both depend on the household's level of being, its situation in its life cycle (family size, age of the head and the spouse), its location... A regression analysis of the logarithm of full prices on these variables (Table VIII) shows that all prices decrease with income, with an average elasticity -0.30 (from -0.13 for transport to -0.15 for food and housing, -0.4 for clothing and other commodities and -0.75 for leisure). They increase with age (except for other expenditures) with an average elasticity 0.4, and decrease with the proportion of children in the family.

5. RESULTS

5.1. The opportunity cost of time

An estimation is made for six activities: expenditures on health and education (where there is no actual expenditure in a number of cases) being included in the last group (Other expenditures). The first estimate is derived from the system of equations (11) which is estimated for 76 sub-populations defined by age groups, income per unit of consumption and family structure. The average estimate of ω is close to the minimum wage rate and smaller than the households' average wage rate.

Using this estimate to calibrate the opportunity cost in the definition of α_i and β_i (equations 9) and using the estimates of the utility coefficients γ_i by equations (11), gives, by equation (7), an average estimate of $\omega=5.0$. This is close to the average estimate from equation (11): 6.03. These values correspond qualitatively to the answer of individuals

in direct surveys on their substitution between time and money, which usually gives an opportunity cost of time that is much lower than the agent's wage rate, net of taxes.

The opportunity costs obtained on individual data (i.e. for each household) by this two-step method is positively indexed on the household's net wage (with an elasticity equal to 0.77) and also on the household's *relative* income (defined as the difference between a household's income and the average income of its sub-population). It also increases with family size, especially with respect to the number of children, which shows that home production is more valued in large families because of economies of scale i.e. the home production of public goods. This means that an increase of the family size may not help to produce more commodities with the same amount of input (which would correspond to economies of scale in domestic production), but that the public goods produced at home in large families profit more numerous families and thus increase the value of time devoted to this production. Table IX (in Appendix) contains the average estimates of the opportunity cost of time for various household types. It shows that, on average, it increases by two thirds between poor singles and rich large families, and more than doubles from the first decile to the last for the whole population.

In order to assess the variation of the estimated opportunity cost of time across the population, a non-parametric estimation of the same system (11) has been performed using the first step of the Lowess procedure²²: for each observation k_0 , a local weighting regression is performed where the weight for k_j is large if household k_j is close to k_0 , small if not and zero outside a neighbouring of household k_0 . The weighting is defined as an Epanechnikov kernel depending on households' income per unit of consumption. This procedure gives rise to local estimates of the opportunity cost of time for each household in the survey. The resulting estimates of ω averages 1.28 (s.e. 0.83) by equation (11) and 2.48 by the second step (equation 7). Both estimates are positively correlated with household's monetary income (elasticities 0.4 and 0.6 respectively) and with the age of the household head: the OCT increases until the age of 40, then decreases as found in previous estimations by cell. This is similar to the evolution found by Aguiar and Hurst (2007b), as has already been remarked.

5.2. Income, price and time elasticities for the whole population

In Table IV (fourth column), the full (compensated) price elasticities are estimated on full budget shares, full income and Gronau's full prices using the opportunity cost estimated on grouped data (Table III, first line). The elasticities are very similar to those obtained by other specifications presented in Table VI in Appendix. The estimation of full price elasticities seems to be robust to the specification of the demand system, either on full expenditures or on their monetary components, or using Becker's or Gronau's full prices, and the estimation does not differ much according to the method used to compute the opportunity cost.

²²The Lowess procedure exists in the Stata programs but apply only to a simple linear regression model. The second step of the Lowess procedure eliminates outliers obtained in the first step regression, see Cleveland (1979).

TABLE IV
INCOME, PRICE AND OPPORTUNITY COST ELASTICITIES

	Monetary income*	Full income **	Full income ***	Full price **	Monetary price	Cost of Time	Opportunity Cost	Monetary priceΔ : Grouping method ****	Monetary priceΔ : Strong separability **** $\omega^{-1} = -0.5 - 1.18$
Food	0.936 (0.004)	0.923 (0.004)	0.904 (0.006)	-0.850 (0.004)	-0.270 (0.011)	-0.580 (0.003)	0.116 (0.011)	-0.810 (0.169)	-0.459 - 0.924 (0.011) (0.022)
Housing	0.990 (0.007)	0.951 (0.006)	1.259 (0.012)	-1.020 (0.013)	-0.665 (0.008)	-0.355 (0.005)	-0.279 (0.026)	-0.383 (0.150)	-0.680 - 1.136 (0.008) (0.012)
Clothing	1.113. (0.023)	1.156 (0.018)	1.475 (0.045)	-1.013 (0.009)	-0.661 (0.003)	-0.351 (0.003)	-0.221 (0.034)	-0.527 (0.066)	-0.635 - 1.281 (0.017) (0.037)
Transport	1.184. (0.010)	1.148 (0.009)	1.187 (0.013)	-0.746 (0.009)	-0.373 (0.004)	-0.374 (0.004)	-0.055 (0.040)	-0.549 (0.010)	-0.543 - 1.191 (0.023) (0.023)
Leisure	1.005 (0.007)	0.993 (0.005)	0.853 (0.007)	-0.888 (0.007)	-0.204 (0.002)	-0.684 (0.005)	0.158 (0.022)	-1.306 (0.032)	-0.532 - 1.074 (0.014) (0.028)
Other	0.907 (0.022)	1.041 (0.015)	0.749 (0.034)	-0.987 (0.006)	-0.348 (0.002)	-0.639 (0.005)	0.063 (0.017)	-0.953 (0.142)	-0.592 - 1.245 (0.018) (0.037)

* Estimation A in Table V: Almost Ideal Demand System with monetary budget shares and income, and Becker's full price p_i^{f2} calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table I). Estimation under homogeneity and symmetry constraints. Quality effects corrected by Deaton's method.

** Estimation B in Table V: Almost Ideal Demand System with full budget shares, full income, and Gronau's full price p_i^{f1} (under the assumption of substitutability of monetary expenditures and time uses), all calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table I). Estimation under homogeneity and symmetry constraints. Quality effects corrected by Deaton's method.

**** Combining the monetary income and time elasticities, equation (A1) in Appendix.

***** Hicks-Lewbel grouping method Ruiz (2006).

***** Frisch formulas for the own-price and cross-price elasticities E_{ii} and E_{ij} ($\Phi = \omega^{-1} = -0.5$ or -1.18 ; $E_i =$ income elasticity; $\delta_{ij} = 0, i \neq j$; $\delta_{ij} = 1, i = j$): $E_{ij} = \omega^{-1} \delta_{ij} - w_j E_i (1 + \omega^{-1} E_j)$; see a discussion of the calibration of the income flexibility $\hat{\omega}$ in Gardes (2014).

Some important results follow from these estimations: first of all, it can be observed that all the (compensated) monetary own-price (*input goods*) elasticities (Table IV, fifth column) are significantly negative. The estimates range from -0.6 and -0.3 and average -0.47²³. These values do not contradict usual estimates on individual data: for instance, elasticities for food are generally small (around -0.5), elasticities for housing even smaller (around -0.3), which are close to the estimates here. Elasticities for transport are often larger, but they depend on the composition of these expenditures between public and private transport and on the definition of expenditures (which include the purchase of vehicles in the dataset here). No clear relationship appears on statistics between the monetary own-price elasticities (Table IV) and the elasticities of substitution (Table I).

Second, it can be observed that the correction of quality decreases the magnitudes of the price-elasticities estimates by an average of 24%, both for full price elasticities and for monetary and time elasticities (all elasticities in Table VI and Table IV are presented after this correction). This is consistent with the theory, as the quality is included in the price, so once the quality effect is corrected the elasticity is smaller.

Third, regarding the estimation under a strong separability assumption on utility (Table IV, last column) based on Frisch's theory, we can observe a significant distance with our estimates. The monetary price elasticity parameters under strong separability (calibrating the income flexibility $\tilde{\omega}^{-1} = -0.5$ as proposed by Frisch and Theil, see Selvanathan (1993) and Theil, Suhm, Suhm, and Meisner (1981)) have a larger magnitude than those estimated without the latter restriction among the 6 commodities. Moreover, the estimation under separability depends heavily on the calibration of the income flexibility (this parameter is estimated as -1.18 on the dataset using a Rotterdam model, which changes significantly the price-elasticities as shown in Table IV). The hypothesis of strong separability can therefore be rejected²⁴. By contrast, the *grouping method*²⁵ (8th column in Table IV) provides close price parameters except for Leisure activities for which this method gives very large price elasticities in absolute values (the method is conditional on the instrumentation of prices derived from the grouping which leads it to being not very robust, as shown by various estimates presented in the Ruiz's PhD, Ruiz (2006)).

Fourth, all elasticities with respect to the total cost of time use $\omega\tau_i$ (depending both on the opportunity cost of time and on the time used by unit of marketed good) are negative. It should be noted that two types of elasticities exists in the model with respect to the time input: those related to the opportunity cost ω and those related to the quantity of time t_i spent for activity i . These parameters thus differ from the elasticity with respect to the cost of time by unit of activity: $\omega\tau_i$ with τ_i the time by unit of market good in the complementary case. The change of the opportunity cost of time has also a direct effect on full income, which is taken into account by this variable in the specification of the demand functions. Their magnitudes do not seem to be related to the values of the income elastic-

²³Note that the price elasticities derived from alternative methods on our dataset (two last columns in Table IV) have larger values than those obtained by our model.

²⁴Note however that the Pigou's law (which relates the direct price elasticity E_{ii} with the income elasticity E_i : $|E_{ii}| = 0.5E_i$, applies rather well to the average estimate of this ratio (column 4 over column 1): 0.57, very close to the average Pigou's ratio (0.60) for the calibration of ω^{-1} at -0.5.

²⁵Individual prices for detailed items (such as bread, sugar...) are grouped into semi-aggregates (food) using the household's budget-shares. The corresponding price index (for food) thus changes between households (see a critical view on this method, for instance in the recent application by Ruiz (2006) in Gardes (2014)).

ities nor to monetary *own*-price elasticities. Their definition by equation (20) shows that this is caused by the absence of a systematic relationship between the monetary and time components of the full expenditures (as shown by Table II). The elasticities of substitution between money and time are estimated with this dataset (see Table I) between 0.41 (for food) and 1.27 (for leisure), which corresponds in most of a household's activities to a weak substitutability. It is thus normal that the elasticities with respect to time use differ from those with respect to money prices. The elasticities of expenditures with respect to the opportunity cost of time ω (equation (21)) are estimated to be between -0.28 and +0.16. The increase of the opportunity cost of time increases the cost of full expenditures and thus normally has a negative effect on them. But it also increases the ratio of the monetary component over the time component (through the positive elasticity of substitution): the total effect on monetary expenditure is therefore either positive or negative according to these two consequences. These elasticities are positive for Food, Leisure and Other activities, and negative for Transport, Clothing and Housing: these values are partially explained by the role played by time for each type of expenditure (the proportion of time in the full expenditures for leisure is for instance equal to 81%, compared to 57% for all other expenditures). It is difficult to estimate the relative roles of the parameters α , β and γ in the variations of this opportunity cost of time, since their relations (in equations 7 and 10) are complex. I leave this analysis for future research using non-parametric estimates of these parameters for each household.

Finally, price elasticities can be computed for disaggregate items of each broad set of expenditures, such as different types of food consumption or expenditures for private versus public transport. The method is based on a separability assumption inside the broad consumption group and is presented in Gardes (2017).

Concerning the full income elasticities, they are not an average of those estimated with respect to the two components - money and time - of the full income, as indicated by the relationship which exists between these parameters (equation A1 in Appendix A). Overall, they indicate the same order between activities as the monetary order, except for the last category (Other Expenditures). It includes various items and is thus difficult to interpret.

5.3. Estimates for sub-populations

Price and time elasticities change significantly between different types of households, for instance between singles, couples without children and families with children: all price effects (as well as the elasticities over time or against the opportunity cost for time) increase with the family size. The larger sensitivity to prices for large families can be related to the notion that household's needs increase (conditional to income) with their size (see Gardes and Merrigan (2008)). On the other hand, as noted by a referee to this article, larger households are likely to be less constrained in their labor decisions, compared to small families or singles. A more complete analysis of intra-household allocation decisions and a comparison between singles and larger families are needed to understand fully this greater sensitivity to prices. Such an analysis could be derived from the estimation of a collective model over full expenditures, which is left for a future research (see for instance Bonke and Browning (2009) for an analysis of a Danish survey containing information of the assignments of expenditures across the different members of the family).

Table X in Appendix indicates the elasticities with respect to full income and monetary

prices for households corresponding to *different seminal types along their life cycle*: first (sub-population P1), singles aged no more than 27; second (P2), couples without children aged 28 to 40; third (P3), couples with children aged 41 to 60; fourth (P4), couples without children aged more than 60. Price elasticities are clearly more dispersed than income elasticities. Second, young singles and old couples are less sensitive to monetary prices than couples in the middle of their life-cycle. Third, it is interesting to note that the ratio of monetary price elasticities to full income elasticities (supposed to be -0.5 according to the Pigou's law) is on average 0.549 (s.e. 0.049 in a regression without a constant for the 24 elasticities of Table VI; $R^2 = 0.16$), which is not contrary to this law, on average.

CONCLUSION

This article provides three methodological contributions: i) the discussion of econometric problems arising from the matching of a Family Budget and a Time Use survey; ii) a model to estimate the opportunity cost of time; and iii) the definition of two alternative full prices and the estimation on cross-sectional micro data of elasticities with respect to monetary prices, time use and the opportunity cost of time. Becker's model of domestic production and the allocation of time proves convenient to define a new method to estimate the opportunity cost of time. My estimations prove that OCT is much lower than the household's average wage rate. It increases with the presence of children, with the household's net wage and its relative income (compared to a reference population). The parameters of the (Cobb-Douglas) domestic production functions and utility are estimated locally (i.e. for each household), so that they correspond to local substitutions for the corresponding household (which do not apply to differences between households). The constancy of the coefficients in the Cobb-Douglas specifications thus applies only in a small neighbourhood for the corresponding household. The estimation of the value of time using this model allows Gronau's "central problem" to be answered concerning the valuation of domestic production²⁶.

All the analysis has been made under the assumption that no interaction exists between the activities considered in the empirical application, as the direct utility function is supposed to be strongly separable. This assumption may be more realistic for broad activities than for more precise ones. The definition of these activities is driven by the possibility of measuring the corresponding monetary and time components in the surveys across expenditures and time uses. It is thus difficult to test the model for a larger number of activities. On the contrary, the definition of a unique utility for the household could be relaxed (note that of time uses are available for individuals in time use surveys, which may be used to test a collective model of decision-making compared to a unitary model).

The model here furnishes precise and quite realistic price elasticities, which compare well with other estimation techniques applied to cross-section data. The two alternative definitions of full prices under complementarity or substitution between the monetary and time factors of the domestic production, seem to afford good proxies to measure the scarcity of commodities. Moreover, the model allows the elasticities for time use and the

²⁶ A possible application of that valuation uses ω to estimate the value of a life: suppose that the individual values (at age 20) all hours during her life (lasting 60 years with a yearly discounting rate at 2%) at this opportunity cost, the total value of her life would be around 2,4 billions of dollars, not so different from the value of life obtained by various methods (see Gardes (2018) and the meta-analysis by Bellavance, Dionne, and Lebeau (2009)).

opportunity cost of time to be computed, and offers a new method to estimate a household's labor supply function. Indeed, an alternative approach to the classic estimation of the agent's labor supply involves recognizing that market labor supply is, in this model, the complement of domestic production, their sum being equal to the total time available (after deducing the time devoted to sleeping and other activities necessary to survive). This shows that it should be possible to estimate labor supply elasticities indirectly, through the estimation of time use functions for home production and consumption (see Gardes and Margolis (2015)).

The definition of broad commodities in this model is necessitated by the matching of time use with monetary expenditures, which cannot be made at a disaggregated level. Micro-simulation exercises need often to calibrate income and price effects at a more precise level of expenditures, for instance for alcoholic beverages when a specific tax is applied to them. This is possible under separability assumptions inside the broad group of commodities considered as activities in the present analysis (see Gardes (2014)). On the other hand, elasticities with respect to the time component of the commodity costs can be useful to analyze the consequences of changes in the commercialization of market goods, transport technology or leisure activities.

For the whole population, the inequality comprising both monetary and time resources is shown to be lower than the inequality computed only for monetary income. The question whether these inequalities have changed over time also merits future analysis. Another application of the definition of full expenditures and full prices includes the computation of the full costs of adults and children in the family: an estimation on the same dataset (Gardes and Starzec, 2018; Gardes, Sayadi, and Starzec, 2015) proves that the full cost of a child compared to a supplementary adult is greater than the same ratio for monetary costs, which may have important consequences in terms of public transfers. The definition of individual prices on the cross-sectional survey also makes it possible to prove the existence of substitution through prices (in the Barten's or Lewbel's Independent of a Base models) in the estimation of equivalence scales. Finally, inequality indexes computed on full income with these equivalence scales are much smaller than inequality of monetary incomes. An interesting point would be to evaluate the recent trends in these two types of income inequality during the recent great recession (see preliminary analyses in Gardes, Sayadi, and Starzec (2015) and Alpmann, Gardes, and Salazar (2016)).

Various assumptions have been made to develop the model: first, the labor market decision is separable from the home production decisions, as is usual in the literature. Second, no joint production exists in domestic production. Third, the model is unitary, in the sense that each household is supposed to maximize a unique utility function. Fourth, the utility and the domestic production functions are specified as Cobb-Douglas functions, but are estimated locally (for each household). This allows the proportion of the two factors to differ across the population. Finally, the theoretical restrictions of the demand system (Symmetry of the Slutsky matrix, homogeneity of demand functions) are supposed to hold. An interesting generalization of the model would be to test the unitary hypothesis using the individual information (for each spouse) available in time use surveys.

APPENDIX A: ECONOMETRIC METHODOLOGY

THE DEMAND SYSTEM

The Almost Ideal Demand System is the most commonly used model to estimate demand elasticities. Four specific problems appear in the estimation of this demand system on matched data: *first*, making the

assumption that full expenditures follow an independent optimization scheme, based either on a utility function or a cost function, implies a total substitution between time and monetary household's expenditures. An alternative assumption would be to suppose that two independent optimizations exist for monetary and for time allocations, but in this case the demand system for full expenditure cannot in general be similar to the equations for monetary and time expenditures. If for instance the cost functions for the monetary and the time expenditures are supposed to be Piglog, both demands are specified as an Almost Ideal demand system (with different parameters). But in that case, the budget share for full expenditures w_{if} depends on the monetary and time budget shares: $w_{if} = \frac{y_m w_{im} + y_t w_{it}}{y_m + y_t}$ and the resulting demand equation for full expenditure cannot be written under as Almost Ideal specification because of the non-linearity in the income variable.

Following this hypothesis of two separate optimizations for the components of the full expenditure, we can calculate the full income elasticity E_{if} in terms of the monetary and time elasticities E_{im} and E_{it} :

$$E_{if} = E_{im} \frac{w_{im}}{w_{if}} \cdot \frac{1}{1+k} + E_{it} \frac{w_{it}}{w_{if}} \cdot \frac{k}{1+k} \quad (A1)$$

with k the derivative of the temporal income over the monetary income and w_{im} , w_{it} and w_{if} the monetary, time and full budget shares of commodity i . The income coefficient can then be fixed by equation (A1) in the estimation of the full expenditures demand system²⁷. This procedure (calibrating the income coefficient and using a Working form for demand functions, corresponding to the linear version of the Almost Ideal demand system) could give a robust method to test for endogeneity biases in the estimation of own-price elasticities. It gives approximately the same estimates than the Almost Ideal Demand System specification that I use here (see Gardes (2014) Tables III and V).

The estimation of two separate system of equations, one concerning monetary expenditures, the other one time uses, can be performed simply under usual theoretical constraints (additivity and homogeneity) which apply separately to each system. The symmetry constraints which apply to the cross-price elasticities can be simply taken into account in a two steps estimation, with some dependencies between the coefficients of the two systems (see Alpman (2016) chapter 5).

QUALITY EFFECTS

Second, quality effects are likely to exist in full price and expenditure data. Indeed, an increase (in the cross-section dimension i.e. between two households) of the full price for commodity (activity) i may result either from the difference (between the two agents) of the opportunity cost ω or from the difference of their time allocated to activity i . Both causes may increase the quality of this activity, by means of an increased productivity (which can be supposed to be positively related to ω) or of the time devoted to i . This endogenous quality appears in the same form as in Deaton's technique to estimate price-elasticities on local prices after removing the quality incorporated in unit values (which is the ratio of expenditures over quantities consumed). In our matched dataset, local prices are replaced by the individual full prices for each household.

Deaton (1988) shows that the elasticity of expenditures C_i over its unit value V_i writes:

$$\varepsilon_{ip} = \frac{\partial \ln C_i}{\partial \ln V_i} = \frac{E_{ip}}{1 + \eta_i \frac{E_{ip}}{E_{iy}}}$$

with E_{ip} the true price-elasticity, E_{iy} the income-elasticity and η_{ϵ_i} the income-elasticity of the unit value. This formula allows calculating the true price-elasticity in terms of the other parameters. In order to estimate $\eta_i = \frac{\partial \ln V_i}{\partial \ln y}$, the two equations model (Deaton's equations 14 and 15) is written for household h in cluster C :

$$w_{hC} = \alpha_1 + \beta_1 \ln y_{hC} + Z_{hC} \gamma_1 + u_{1hC} \quad (A2)$$

$$\ln V_{hC} = \alpha_2 + \beta_2 \ln y_{hC} + Z_{hC} \gamma_2 + u_{2hC} \quad (A3)$$

²⁷Note that income is not deflated since households are supposed to face the same monetary prices. Full prices are used as indicators of scarcity for the household's consumption and are not supposed to change the level of the household's monetary or full income.

with w_{hC} the budget share for household h in cell C .

I define clusters as groups of households which are supposed to have the same opportunity cost of time and the same domestic production functions (thus the same τ_i for all i) for instance by means of a common age class, location and education of the head. I thus estimate $\eta = \beta_2$ by (A3) within clusters and $E_{ip} = \gamma_1$ and $\beta_1 = E_y$ by (A2) with the full individual prices included in Z_{hC} .

BOOTSTRAP PROCEDURE

The *third problem* concerns the correction of variances necessitated by the fact that budget times are generated regressors being predicted for each household of the Family Expenditures survey from the time budgets recorded in the Time Use survey. These estimated times are added to the household's monetary expenditures to form the household's full expenditures. These expenditures serve to calculate indices of scarcity which are used as full prices π in the estimation of the demand system $h(x, \beta, W, \pi)$ where W is the set of variables used in the first step to predict π , α and β and the parameters of the demand functions. Thus, the full prices are generated in a first step before the estimation of the demand system, which necessitate correcting the estimated variances. Murphy and Topel (1985) proposed a method adapted to this case. Their theorem states that the second step estimator β is consistent and asymptotically normal with an asymptotic covariance matrix (as stated by Greene (2018)):

$$V_{\beta^*} = \sum_{b=1}^2 V_b + V_b \left[CV_C C' - CV_C R' - CRVC' \right] V_b$$

where V_b is the covariance matrix given by the second step of the estimation, $C = n.plim \left[\frac{1}{n} \sum_{i=0}^n x_i^0 \hat{\varepsilon}_i^2 \left(\frac{\partial h(x, \beta, w, \pi)}{\partial \pi} \right) \right]$ and $R = n.plim \left[\frac{1}{n} \sum_{i=0}^n x_i^0 \hat{\varepsilon}_i \left(\frac{\partial g(w, \pi)}{\partial \pi} \right) \right]$ with g depending on the log-likelihood function. In the case where π is predicted by a linear regression, C can be written:

$$C = d \sum_{i=1}^n e_i^2 x_i w_i$$

with e_i the error term of the demand function in the second step and d the coefficients in the estimation of π in the first step. R is null if the regression disturbances of the regression in the first and second steps are uncorrelated, which is the case of our model since full prices are predicted from the Time Use surveys and used as a regressor on the family Expenditures survey. Finally, we obtain $C = \sum_{i,j} d_i d_j d_{ij}$ depending on the coefficients and covariance terms of the first step regression.

A simple bootstrap procedure is, for our model, a simple alternative to the Murphy-Topel method. Consider that the full prices are estimated using the activity times predicted by the actual times observed in the Time use survey and can be considered as instrumented values of the actual full prices. The usual method to correct the variances in case of instrumentation compares the residuals $\hat{\varepsilon}_1 = y - X\hat{\beta} - \ln\pi^{IV} \cdot \hat{\gamma}^{IV}$ estimated in the second step regression using the logarithmic prices defined by the predicted times with the residuals $\hat{\varepsilon}_2$ computed with the parameters $\hat{\beta}, \hat{\gamma}^{IV}$ issued from instrumentation and the actual value for full prices $\ln\pi$: $\hat{\varepsilon}_2 = y - X\hat{\beta} - \ln\pi \cdot \hat{\gamma}^{IV}$. In the case here, actual full prices π_i are not observed in the monetary statistics. But they can be simulated, when the distribution is known for the set of prices for household h issued from the prediction of prices: $\ln\pi_{ih} \sim N(\ln\pi_i^{IV}, V_i)$ supposed to be normal (as indicated by the distribution of the logarithmic full prices) with the estimated price as the mean of the distribution. The variance $V_i = Var(\ln\pi_i)$ of the logarithmic price for activity i is estimated by the empirical variance of the logarithmic full prices $\ln\pi_i^{IV}$ computed on the monetary expenditures survey. Therefore, this residual writes for household h :

$$\hat{\varepsilon}_2(h) = \hat{\varepsilon}_1(h) + \sum \hat{\gamma}_i [\ln\pi_i^{IV}(h) - \ln\pi_i(h)]$$

so that: $V(\hat{\varepsilon}_2) = V(\hat{\varepsilon}_1) + \sum \hat{\gamma}_i^2 V_i$.

This procedure will be preferred because of its simplicity and the fact that it takes fully into account the non-linear nature of predicted logarithmic full prices. Both procedures give similar inflation of standard errors (for instance 156% and 165% for housing expenditures, 119% and 152% for transportation).

TABLE V
ESTIMATION OF THE SYSTEM OF EQUATIONS (11)

	OCT	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	$\sum \gamma_i$
Constrained	1.009	0.165	0.250	0.121	0.051	0.184	0.229	1
s.e.	(0.0311)	(0.0008)	(0.0011)	(0.0007)	(0.0005)	(0.0013)	(0.0020)	
Unconstrained	*	0.138	0.202	0.151	0.090	0.202	0.208	0.991
s.e.		(0.0012)	(0.0010)	(0.0014)	(0.0011)	(0.0014)	(0.0167)	0.0169

* $\omega_1 = 0.294(0.042)$; $\omega_2 = 4.470(0.101)$; $\omega_3 = 2.287(0.060)$; $\omega_4 = 62.930(0.046)$; $\omega_5 = 1.164(0.046)$; $\omega_6 = 0.208(0.017)$

POTENTIAL ENDOGENEITY BIASES

Finally, endogeneity may appear in the full demand equations because the opportunity cost of time and the unit time for activity τ_i appear both in the full expenditure for i , in the full total expenditure and in the vector of the proxies for full prices for all commodities. This problem exists because full prices are endogenous, depending on the household type and characteristics (in classic demand systems, prices are on the contrary pre-determined and generally supposed to be constant across the population). This possible endogeneity bias could be taken into account by an instrumentation of full prices and full total expenditure. Results on instrumented income are similar to those of Tables III and V. Also, it is possible to calibrate the full income elasticity by formula (Table V), using monetary and time elasticities estimated by two demand systems written respectively on monetary and time expenditures. In my estimations, I check that defining prices by an alternative valuation of time than the one which is used to calculate full budget shares (specification A in Table V) gives close results to those using the opportunity cost to value all variables. Another way to estimate full price elasticities consists in estimating the demand system on monetary expenditures and the proxies of full prices (specification A in Table VI). All specifications give negative and significant price elasticities which are close (up to 13% in average).

TABLE VI
FULL PRICE ELASTICITIES UNDER DIFFERENT SPECIFICATIONS OF THE DEMAND SYSTEM (NOT
CORRECTED FOR QUALITY EFFECTS)

Activity	A	B	C	D	E	F
Food	- 1.015	-1.108	-1.042	-0.987	-1.047	-0.984
	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.019)
Housing	- 1.182	-1.281	-1.175	-1.152	-1.251	-1.342
	(0.008)	(0.008)	(0.008)	(0.008)	(0.010)	(0.012)
Clothing	- 1.381	-1.533	-1.433	-0.968	-1.447	-0.877
	(0.008)	(0.010)	(0.009)	(0.006)	(0.010)	(0.067)
Transport	- 1.183	-1.348	-1.210	-1.199	-1.197	-1.823
	(0.008)	(0.010)	(0.009)	(0.008)	(0.009)	(1.419)
Leisure	- 0.801	-0.888	-0.799	-0.808	-0.832	-0.628
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.051)
Other	- 1.198	-1.360	-1.247	-1.220	-1.254	1.409
	(0.007)	(0.007)	(0.007)	(0.014)	(0.008)	(12.94)

Specifications: A. Almost Ideal Demand System with monetary budget shares and income, and Becker's full price p_i^{f2} calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table III). Estimation under homogeneity and symmetry constraints.

B. Almost Ideal Demand System with full budget shares, full income, and Gronau's full prices p_i^{f1} , all calculated with the opportunity cost of time $\hat{\omega}$ estimated on individual data (equation (7), Table III). Estimation under homogeneity and symmetry constraints.

C. Almost Ideal Demand System with full budget shares, full income, and Gronau's full price p_i^{f1} , all calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table III). Estimation under homogeneity and symmetry constraints.

D. Almost Ideal Demand System with full budget shares, full income, and Becker's full price p_i^{f2} , all calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table III). Estimation under homogeneity and symmetry constraints.

E. Almost Ideal Demand System with full budget shares (valuated by the minimum wage rate), full income and Gronau's full prices calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table III). Estimation under homogeneity and symmetry constraints.

F. Quadratic Almost Ideal Demand System (QUAIDS) with full budget shares, full income, and Becker's full price, all calculated with the estimated opportunity cost of time $\hat{\omega}$ on grouped data (equation (11), estimation on 76 cells, Table III). Estimation under homogeneity and symmetry constraints.

TABLE VII
INEQUALITY INDEX COMPARED FOR MONETARY AND FULL INCOMES

Whole Pop.	P1	P2	P3	P4
0.428	0.371	0.274	0.284	0.365
0.393	0.176	0.240	0.281	0.321
0.389	0.175	0.237	0.279	0.320

Standard error of logarithmic expenditures. Full expenditure computed using the opportunity cost estimated by cell (Table III, equation 11). Equivalence scales are estimated on the same dataset in Gardes and Starzec (2018).
 \hat{Y}^{mon} : monetary expenditure per Unit of Consumption (equivalence scale estimated on monetary expenditures).
 \hat{Y}_1^{full} : full expenditure per Unit of Consumption (equivalence scale estimated on monetary expenditures).
 \hat{Y}_2^{full} : full expenditure per Unit of Consumption (equivalence scale estimated on full expenditures).

TABLE VIII
DETERMINANT OF FULL PRICES

	Income	Income2	Age	Age2	ES	Prop. Child	R^2
Food	-4.21	0.22	-21.94	3.10	1.58	-2.00	0.191
s.e.	(1.22)	(0.06)	(1.25)	(0.17)	(0.07)	(0.12)	
Housing	-0.70	0.0001	1.61	0.14	2.64	-3.77	0.470
s.e.	(1.25)	(0.07)	(1.28)	(0.17)	(0.07)	(0.13)	
Clothing	-2.47	0.06	-8.46	1.54	-1.38	-2.46	0.250
s.e.	(1.78)	(0.09)	(1.42)	(0.24)	(0.10)	(0.18)	
Transport	3.63	-0.19	-18.98	2.64	-0.88	0.46	0.193
s.e.	(1.20)	(0.06)	(1.23)	(0.16)	(0.07)	(0.12)	
Leisure	-1.65	-0.01	-27.06	3.77	-1.88	-5.54	0.453
s.e.	(1.26)	(0.07)	(1.29)	(0.17)	(0.07)	(0.13)	
Other	-12.15	0.56	-29.45	3.56	0.32	-1.06	0.263
s.e.	(1.41)	(0.07)	(1.44)	(0.19)	(0.08)	(0.14)	

All variables in logarithm. Full prices under substitution (p_2^f). ES: equivalence scale (first adult: 1; second adult: 0.7; children: 0.5).

TABLE IX
VARIATION OF THE OPPORTUNITY COST OF TIME

	All population	Singles	Couples without child	Couples without 1 Child	Couple with 2 Children	Large families ***	Single poor ****	Other rich *****
Omega by cell *	6.24	5.98	6.24	6.98	6.47	5.48	5.19	8.53
s.e.	(1.02)	(1.51)	(2.36)	(1.88)	(1.84)	(1.55)	(1.41)	(1.98)
Omega i.d. **	4.74	4.84	4.47	4.92	4.93	5.09	4.74	4.93
s.e.	(0.86)	(0.94)	(0.81)	(0.96)	(0.55)	(0.75)	(0.94)	(0.77)
Wage	6.92	6.99	6.81	7.08	7.20	6.60	6.04	10.50
s.e.	(2.70)	(2.99)	(2.61)	(2.47)	(2.62)	(2.64)	(2.27)	(2.89)
Income per U.C	15427	16580	17240	14463	12347	9126	4993	38029
Age	50.9	55.4	57.6	41.8	39.9	41.4	49.8	53.0

* All population: 1st decile: 3.86; 9th decile: 8.77.
** Estimated on individual data by equation (7). All population: 1st decile: 3.89; 9th decile: 5.58.
*** Large families: couple with more than 4 children.
**** Singles with income per UC smaller than the first decile of the whole population.
***** Couples with income per UC larger than the last decile of the whole population.

TABLE X
FULL INCOME AND MONETARY PRICE ELASTICITIES FOR SUB-POPULATIONS

	Food		Housing		Clothing		Transport		Leisure		Other	
	Y ^f	p ^f	Y ^f	p ^f	Y ^f	p ^f	Y ^f	p ^f	Y ^f	p ^f	Y ^f	p ^f
P1	0.908	-0.284	1.367	-0.839	1.167	-0.790	0.669	-0.437	1.096	-0.205	0.992	-0.311
P2	0.886	-0.325	1.017	-0.835	1.081	-1.063	1.091	-0.654	0.988	-0.179	1.141	-0.612
P3	0.909	-0.325	0.966	-0.739	0.977	-0.985	1.055	-0.697	1.073	-0.319	1.049	-0.752
P4	0.906	-0.241	1.023	-0.571	1.064	-0.489	1.055	-0.542	0.992	-0.141	1.092	-0.764
P	0.927	-0.297	0.950	-0.618	1.098	-0.751	1.144	-0.536	1.002	-0.164	1.041	-0.552

Specification: C (Table V)
Sub-populations: P: all households; P1: singles aged less than 27; P2: couples without children, aged 28-40; P3: couples with children, aged 41-60; P4: couples without children aged more than 61.

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