Heterogeneity in Consumer Demand - Evidence from Panel Data : a Rejoinder

François Gardes, Paris School of Economics, Université Paris 1 Panthéon Sorbonne
106-112 Bld de l'Hôpital 75013 Paris
gardes@univ-paris1.fr
Christophe Starzec, CES, Université Paris 1 Panthéon Sorbonne
106-112 Bld de l'Hôpital 75013 Paris
starzec@univ-paris1.fr

Preliminary version

Abstract

Christensen (2014) examines in an article of this Journal the endogeneity biases which characterize a majority of monetary households' expenditures. The estimation of full expenditures, integrating monetary expenditures and time use for domestic activities, allows taking fully into account the role of prices and the complementarities between monetary and time expenditures. The results show the importance of integrating domestic production to households' market activities in an interpretation of these endogeneity biases on cross-sectional consumption surveys.

Key words: time allocation, opportunity cost of time, full expenditure, full price, cross-section, time-series, panel, income elasticity, price elasticity

JEL: C33, D1, D13, J22

Field : Microeconomics, consumer, econometrics of panel data

Introduction

Unobserved heterogeneity can be largely reduced when observing economic agents over several periods, which allows the estimation of permanent specific effects (such as those related to the education level or the location of the economic agent). Gardes et al. (2005) shows that the classic difference between the cross-section and time-series estimates of the food income elasticity can be explained partially by the increase of the full price for food (including its monetary cost and the opportunity cost of time used for food activities) over the income distribution: the positive elasticity of that full price with respect to the relative income position of the households biases negatively the cross-section income elasticity for food at home and positively the income elasticity for food taken away from home. Resuming this analysis, Christensen (2014) examines the same type of bias for all consumptions observed in a Spanish panel and obtained significant biases for two third among all commodities. The same conclusion was obtained on French and Canadian pseudo-panel data (Cardoso and Gardes, 1996; Gardes et al., 1996).

Christensen (2014) concludes that half of the goods considered have biased income elasticities in the cross-section dimension, which corresponds to the results of similar estimations (comparing cross-sectional and time-series data in France and Canada) in Cardoso and Gardes (1996) and Gardes et al. (1996). But her method is rather confused: does she estimate in the within dimension? With or without a constant? Why does she use a *linearized* Quaids? How does she take into account economies of scale and more generally equivalence scales? Finally, she explains the result by "changing preferences". We shall try to explain it instead: first full prices taking into account a part the consumers heterogeneity; second, by the estimation of full income elasticities; third, by non-linear income effects (by an EASI); fourth, by habits (estimating a dynamic specification).

Three questions are thus examined in this paper: first, are these biases related to some non-linear relation in the income-expenditures relationship: in that case, taking care of these non-linearities by polynomial demand function with an order greater than one or two (in the case of the linear and quadratic Almost Ideal Demand systems), such as the EASI system of demand (Lewbel and Pendakur, 2009), may cancel these endogeneity biases. Second, heterogeneity between consumers may proceed from different price conditions – either related to different full prices whenever consumers face the same monetary price system, or to virtual prices arising from constraints or non-monetary ressources. We estimate in this paper using full prices issued from a domestic production model, which allows taking care of the heterogenous time constraint between households. Third, it may be interesting to compare the cross-section and time-series estimates of *full* income elasticities (as well as the one involved for time elasticities), which is possible with our dataset matching four year of a consumer Polish panel with a Time Use survey.

The domestic production framework is presented in section 2. Section 3 discusses the econometric methodology while section 3 presents the dataset. The last sections give the results of the estimations and conclude.

Section 1. Theory and empirical definition of the full prices

Becker (1965) considers a set of *final goods* which are the arguments of the consumer direct utility of the consumer. In order to simplify the analysis, Becker (1965) states that a separate activity i produces the final good i using a unique market good in quantity x_i and unit time t_i per unit of activity i (an hypothesis which can be generalized easily). Finally, the two factors of the domestic production functions can be supposed to be complementary, as in Becker's (1965) analysis, or substitutable, as in Gardes (2016). These two assumptions allow to derive full prices which can be measured on or dataset matching monetary expenditures and time use.

The opportunity cost of time is derived from a model of direct utility maximization in a domestic production framework (Gardes, 2014) which is presented in Appendix A. The opportunity cost of time ω is calculated in this model as the ratio of the marginal utilities for time over the marginal utility of money.

We propose two definitions of full prices, based on alternative assumptions about the substitutability between time and monetary expenditures. First, the derivation of the equation defining the full expenditures in terms of its monetary and time component allows calculating the full price for the model presented in section 1. In that case, full prices depend on the estimates of the parameters of the utility and domestic production functions α, β and the opportunity cost of time ω. The alternative definition relies on the complementarity of the two factors which characterizes the Becker's model. In that model, the full price is the sum of the monetary price and the cost of time to produce one unit of the final good. It can be approximated by a formula which depends only on the estimate of the opportunity cost of time. Finally, a relation is established between the two definitions.

1.1. Full prices for substitutable factors

Following Becker and Michael (1983, equation 10 p. 383)[1], the full expenditure can be written as the sum of its monetary and time components:

$$\mathbf{p^{f1}_{iht} z_{iht} = p_{it} x_{iht} + \omega_{ht} t_{iht}} \qquad (1)$$

with p^f and p the full and the monetary prices corresponding to the quantities z and x of the commodity and of the corresponding market good, for commodity i, household h and time t (the time index will be omitted thereafter as we consider households surveyed during the same period).

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

$$\mathbf{p^{f1}_{iht} = p_{it} \frac{\partial x_{ih}}{\partial z_{ih}} + \omega_{ht} \frac{\partial t_{ih}}{\partial z_{ih}}} \qquad (2)$$

The optimization program gives rise to the first order condition (see Gardes 2016 for the proof):

$$\mathbf{\frac{t_{ih}}{x_{ih}} = \frac{p_{ih}}{\omega_{ih}} \frac{\beta_{ih}}{\alpha_{ih}}}$$

Writing the quantity of the commodity $\mathbf{z_{ih}}$ in terms, either of t or x, gives:

$$\mathbf{t_{ih} = \frac{1}{a_i} z_{ih} \left(\frac{p_{ih}\beta_{ih}}{\omega_h \alpha_{ih}}\right)^{\alpha_{ih}} \text{ and } x_{ih} = \frac{1}{a_i} z_{ih} \left(\frac{\omega_{ih}\alpha_{ih}}{p_h \beta_{ih}}\right)^{\beta_{ih}}} \qquad (3)$$

[1] Suggested by Anil Alpman (see Alpman and Gardes, 2016).

so that the full price becomes:

$$\mathbf{p_{iht}^{f1}} = \frac{\mathbf{1}}{\mathbf{a_i}} \mathbf{p_{ih}^{\alpha_{ih}} \omega_{ht}^{\beta_{ih}}} \left\{ \left(\frac{\boldsymbol{\beta}_{\mathbf{ih}}}{\boldsymbol{\alpha}_{\mathbf{ih}}}\right)^{\alpha_{ih}} + \left(\frac{\boldsymbol{\alpha}_{\mathbf{ih}}}{\boldsymbol{\beta}_{\mathbf{ih}}}\right)^{\beta_{ih}} \right\} \qquad (\mathbf{4})$$

This derivation of $\boldsymbol{\omega}, \boldsymbol{\alpha}$ **and** $\boldsymbol{\beta}$ at the individual level allows identifying the full price for each household ($\mathbf{a_i}$ **being supposed constant across the population**).

1.2. Proxies of full prices for complementary factors

Becker's full price can be written:

$$\mathbf{p_{iht}^{f2}} = \mathbf{p_{it}} + \boldsymbol{\omega}_{\mathbf{h}} \boldsymbol{\tau}_{\mathbf{iht}} \qquad (5)$$

with $\boldsymbol{\tau}_{\mathbf{ih}}$ the time use necessary to produce one unit of the activity i. Suppose that a Leontief technology allows the quantities of the two factors to be proportional to the activity:

$\mathbf{x_{ih}} = \boldsymbol{\xi}_{\mathbf{ih}} \mathbf{z_{ih}}$ **and** $\mathbf{t_{ih}} = \boldsymbol{\theta}_{\mathbf{ih}} \mathbf{z_{ih}}$, so that: $\mathbf{t_{ih}} = \boldsymbol{\tau}_{\mathbf{ih}} \boldsymbol{x}_{\mathbf{ih}}$ with $\boldsymbol{\tau}_{\mathbf{ih}} = \frac{\boldsymbol{\theta}_{\mathbf{ih}}}{\boldsymbol{\xi}_{\mathbf{ih}}}$

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

$$\pi_{iht} = \frac{(\mathbf{p_{it}} + \boldsymbol{\omega}_{\mathbf{ht}} \boldsymbol{\tau}_{\mathbf{ih}}) \mathbf{x_{ih}}}{\mathbf{p_{it} x_{ih}}} = \frac{\mathbf{p_i} + \boldsymbol{\omega}_{\mathbf{h}} \boldsymbol{\tau}_{\mathbf{ih}}}{\mathbf{p_{it}}} = \mathbf{1} + \frac{\boldsymbol{\omega}_{\mathbf{h}} \boldsymbol{\tau}_{\mathbf{ih}}}{\mathbf{p_{it}}} = \frac{\mathbf{1}}{\mathbf{p_{it}}} \mathbf{p_{iht}^{f2}} \qquad (\mathbf{6})$$

Note that this second definition can be also derived from equation (2) with $\frac{\partial \mathbf{x_{ih}}}{\partial \mathbf{z_{ih}}} = \mathbf{1}$ and $\frac{\partial \mathbf{x_{ih}}}{\partial \mathbf{z_{ih}}} = \boldsymbol{\tau}_{\mathbf{ih}}$. Under the assumption of a common monetary price p_i for all households in a survey made during the same period, this ratio contains all the information on the differences of full prices between households deriving from their opportunity cost for time $\boldsymbol{\omega_h}$ and the coefficient of production $\boldsymbol{\tau}_{\mathbf{ih}}$. If the monetary price p changes between households or periods, the full price can be computed as the product of this proxy π_{ih} with p_{ih}: $\mathbf{p_{ih}^{f2}} = \mathbf{p_{iht}} \boldsymbol{\pi}_{\mathbf{ih}}$. With these definitions, it is possible to measure the full prices, observing only monetary and full expenditures by equation (6).

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[2]. It relies on the estimation of three parameters: $\boldsymbol{\alpha}, \boldsymbol{\beta}$ **and** $\boldsymbol{\omega}$. 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 of time $\boldsymbol{\omega}$. 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 (6) we obtain:

$$\mathbf{p_{iht}^{f1}} = \frac{\mathbf{1}}{\mathbf{a_i}} \mathbf{p_i^{\alpha_i}} \left(\frac{\mathbf{m_{ih}}}{\boldsymbol{\omega}_{\mathbf{ht}} \mathbf{t_{ih}}}\right)^{\boldsymbol{\beta}_{\mathbf{i}}} \left\{\mathbf{1} + \frac{\boldsymbol{\omega}_{\mathbf{h}} \mathbf{t_{ih}}}{\mathbf{p_{it}}}\right\} \qquad (\mathbf{7})$$

so that their logarithmic transforms differ only by $\boldsymbol{\beta_i} \log \frac{\boldsymbol{m_{ih}}}{\boldsymbol{t_{ih}}}$ on a cross-section:

$$\log \mathbf{p_{iht}^{f1}} = \textbf{constant} + \boldsymbol{\beta}_{\mathbf{i}} \log \frac{\mathbf{m_{ih}}}{\boldsymbol{\omega}_{\mathbf{h}} \mathbf{t_{ih}}} + \log \boldsymbol{\pi}_{\mathbf{ih}} \qquad (\mathbf{8})$$

with prices $\mathbf{p_{it}}$ set to one for all commodities observed in one survey.

Two hypotheses were necessary to derive full prices from monetary and time expenditures: first, the domestic production functions are supposed to be either Leontief functions with constant coefficients of production (for the second definition) or Cobb-Douglas functions (for the first definition); second no joint production exists, which may be more easily verified for broad categories of activities such as housing and eating.

An important difficulty for such an application of the domestic production model lies in the valuation of time. A Cobb-Douglas specification of the utility and of the domestic production functions allows estimating locally (for each household) the opportunity cost of time by means of the first order conditions for the substitution between time and monetary resources used for the domestic production. Estimations for France (see Gardes, 2014) show that this estimated opportunity cost is close in average to the minimum wage rate and is positively indexed on the household's net wage and on income (conditional to net wage).

Two hypotheses are necessary to derive full prices from monetary and time expenditures: first, domestic production functions are supposed to be Leontief functions with constant production coefficients (note that the domestic production functions are specific for each household) or Cobb-Douglas production functions the parameters of which are estimated locally; second no joint production exists using a common monetary or time expenditure, which may be more easily verified for broad categories of activities such as housing and food (see Pollack-Wachter, 1976, for a discussion).

1.3. Quality effects

[2] Note that the empirical evidence on the elasticity of substitution between time and money in the domestic production functions (see Hamermesh, 2008 and Canelas et al, 2015) gives rather estimates between 0.4 (for food) and 1 for other expenditure groups.

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 used to estimate price-elasticities on local prices after removing the quality incorporated in unit values. In our matched dataset, local prices are replaced by the individual full prices for each household and the quality effects are removed later for a second version of the tests using the Deaton's procedure.

Section 2. Econometric methodology: the QUAIDS and EASI demand Systems

The quadratic Almost Ideal demand system (Banks et al., 1995) allows taking care of some curvature in the income effect. A more flexible system have been recently proposed by Lewbel and Pendakur (2009)which allows to discuss how much the endogeneity which biases income elasticities may be due to the non-linearity of effects on consumption.

The EASI demand system

Lewbel and Pendakur (2009) proposed a general demand system which generalizes the reduced form of the Almost Ideal demand system (Deaton-Muellbauer, 1980) using a polynomial specification to estimate the income effect. The quadratic QUAIDS (Banks et al., 1995) already uses a quadratic income form, while the EASI system allows the inclusion of higher powers of the income term interactions between all regressors. The EASI system has been estimated on macro time-series by Lewbel and Pendakur. In this article we propose to estimate this model on individual data, and to compare it to a semi-parametric demand system based on a neural network.

The EASI system is linear in the income and price parameters and its name has been chosen to stress that it is as easily estimated (possibly in an approximate form) as the AI demand system (without the difficulty imposed by the integrability constraints present in the quadratic QUAIDS). The income parameters can have any possible rank, which allows to estimate all types of Engel curves. Its comparison to the linear AI and to a flexible semi-parametric demand system is therefore important, and this comparison requires a numerous dataset which is provided by the matching of a Family Expenditures survey with a Time Use survey. The EASI system is defined by the following equations, where w^j represents budget shares, p are prices, and z are socio-demographic control variables:

$$w^j = \sum_{r=1}^{R} b_r^j y^r + \sum_{t=1}^{T} g_t^j z_t + \sum_{t=2}^{T} h_t^j z_t y + \sum_{k=1}^{J}\sum_{t=1}^{T} a^{jkt} z_t \ln p^k + \sum_{k=1}^{J} b^{jk} \ln p^k y + \varepsilon^j$$

$$y = \frac{\ln x - \sum_{j=1}^{J} w^j \ln p^j + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J}\sum_{t=1}^{T} a^{jkt} z_t \ln p_j \ln p_k}{1 - \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J} b^{jk} \ln p_j \ln p_k}$$

This model allows us to test different ranks of the income effect, and can capture income and the price effects more complex than those allowed by the AI or quadratic AI demand systems. The system was estimated using the easi R package (Hoareau *et al*, 2012).

System of monetary and time demand functions

Suppose that full expenditures follow an independent optimization scheme, which implies a total substitution between time and monetary household's expenditures. In such a case, a cost Pig-log cost function C(u,p[f]) can be defined over the full prices: $p_i^f = p_i^m(1 + \frac{\omega t_i}{p_i^m x_i + \omega t_i})$ which allows to specify a full expenditures function in terms of the full income and full prices(which can be substituted by our proxies). Endogeneity may appear in the full expenditures specification since 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 instrumentation of full prices and full total expenditure or GMM[3].

It is also plausible 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: $w_{if} = \frac{y_m w_{\mathfrak{Z}} + y_t w_{it}}{y_m + y_t}$ 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. Suppose the full cost function can be decomposed as the product of a monetary and a time cost: $\log(C^f(u, p^f) = log(C^m(u, p^m) + log(C^t(u, p^t)$ which have both a Pig-Log functional form. In that case, the derivation of the monetary demand depends only on the monetary prices and writes:

$$\frac{\partial lnC^f}{\partial lnp_i^m} = \alpha_i + \sum_j \gamma_{ij} \log(p_i^m) + \sum_j \gamma_{ij}\, log(\pi_i) + \beta_i \log(\frac{y^f}{a(p^f)})$$

which implies the following demand equation: $w_i^m = \frac{\partial lnC^m}{\partial lnp_i^m} = \frac{\partial lnC^m}{\partial lnC^f} \frac{\partial lnC^f}{\partial lnp_i^m}$ with $\frac{\partial lnC^m}{\partial lnC^f}$ estimated by means of the empirical elasticity of monetary income over full income (which could differ from unity since it depends on the income elasticity of the opportunity cost of time and on the elasticity of the labor supply). A similar time demand function can be

[3] Note however that estimating monetary expenditures over the monetary income and full prices gives price elasticities which conform to the full demand specification, see Gardes (2015).

recovered from the derivative of the full cost function over the proxies of the full prices π_i. These two demand equations can be estimated as a system under the constraint on price parameter following from the relationship between the monetary and time price elasticities (derived from their relations with the full price elasticity). The time demands have the same structure.

In this paper, we estimate a demand system, first on monetary expenditures, then on full expenditures. These estimation give respectively the monetary income elasticities and the full income ones. As concern price elasticities, the elasticities over the own-monetary price E_{p_i} (as well as the elasticity as concerns the time used for the consumption activity and as concerns the opportunity cost of time) are easily recovered by a simple derivation of their full price elasticities E_{π_i} (see for instance De Vany, 1974) and can be calculated by mean of the full expenditures and its monetary and time components:

$$E_{p_i} = E_{\pi_i} \frac{p_i}{\pi_i} = E_{\pi_i} \frac{p_i x_i}{\pi_i x_i} = E_{\pi_i} \frac{m_i}{m_i + \omega t_i} \qquad (3)$$

The variances are corrected for generated regressors (the full prices depending on the estimates of the opportunity cost of time and of the matched time use) by a bootstrap procedure which gives similar correction as those provided by the Murphy and Topel (1985) method (details are provided in Gardes, 2014).

Section 3. The Dataset

The Polish panel of family expenditures contains 3052 households over four years (1987-90). This panel is matched with one Time use survey conducted in 2003-2004 over approximately 10000 households (20000 individuals). These two surveys and the matching procedure, based on a correspondence between households with the same demographic structures, are described in Appendix I.

Six activities have been defined: food, housing, clothing, transport, leisure and various expenditures (including health services). Their full prices differ both among households and across periods, as shown by the following table.

Work in Progress: full descriptive analysis of the dataset

Section 4. Results: Estimation of monetary and full demand functions[4]

First preliminary empirical results

Almost ideal specification for all goods:

[4] All estimations are reported in Appendix II.

Table 1 contains the income elasticities of six consumption estimated for the 1997 survey (cross-section dimension) and the first difference between 1998 and 1997 surveys.

Table 1
Income elasticities in cross-section and time-series

	Monetary expenditures		Full expenditures	
	CS: 1997 survey	TS: 1997-1998	CS: 1997 survey	TS: 1997-1998
Food	0.655 (0.03)	0.365 (0.010)	0.674 (0.029)	0.639 (0.009)
Housing	1.578 (0.086)	1.460 (0.027)	1.752 (0.135)	1.583 (0.031)
Clothing	1.448 (0.098)	1.222 (0.047)	1.454 (0.097)	1.349 (0.055)
Transportation-Communication	1.170 (0.113)	1.526 (0.038)	1.288 (0.151)	1.958 (0.039)
Leisure	1.229 (0.345)	1.145 (0.043)	0.840 (0.136)	0.771 (0.021)
Other	0.809 (0.199)	0.681 (0.035)	0.803 (0.205)	0.813 (0.034)

The monetary income elasticities are greater in the cross-section dimension, while the full income elasticities are much more similar in the two dimensions. This shows that households tend to organize their domestic production in such a way that potential biases of the cross-section estimates are lower when taking into account the domestic production of full consumptions. As in previous studies a difference appears in both dimensions for more than half of items.

In Gardes (2017), non-parametric tests have been applied to this dataset in order to recover those households the revealed preferences of which cannot be rationalized by a utility function (i.e. households which violate either the weak axiom of revealed prefernece s or the strong axiom). The estimation of the same system of demand in the cross-section dimension (on the 1997 survey, see Tables in Appendix III) shows significant differences, up to %, between the estimation on the whole population (containing households violating the weak or strong axioms of revealed preferences, over 3052 households) and the estimation on non-violating households. This shows that a non-parametric test performed before the estimation of the demand system, in order to eliminate non-rational households, may give more accurate estimates of the income effect.

Work in Progress: estimation of income and price elasticities par a quadratic Almost Ideal demand system for the whole panel in the Between and Within dimension; comparison by Hausman tests of the estimates in the two dimensions.

Estimation of the EASI system.

Conclusion

1. Full prices derived from the original domestic production model allow the estimation of a demand system with individual prices (while Christiansen (2014) uses indices which do not vary among households giving considerably smaller variances).

2. The significant differences between full and monetary elasticities can be interpreted as the influence of the unobserved heterogeneity.

3. The results show that households tend to organize their domestic production in such a way that potential biases of the cross-section estimates are lower when taking into account the domestic production of full consumptions. As in previous studies a difference appears in both dimensions for more than half of items.

References

Becker G.S., 1965, A Theory of the Allocation of Time, *The Economic Journal*, vol. 75, 493-517.

Becker, G.S., Michael, R.T., 1973, On the New Theory f Consumer behaviour, *The Swedish Journal of Economics*, Dec., Vol. 75, 4, 378-396.

Cardoso, N., and Gardes, F. (1996), "Estimation de Lois de Consommation sur un Pseudo-Panel d'Enquêtes de l'INSEE (1979, 1984, 1989), *Economie et Prévision*, 5, 111-125.

Christensen, B., 2014, Heterogeneity in Consumer Demands and the Income Effect: Evidence from Panel Data, *The Scandinavian Journal of Economics*, 116, 2, 335-355.

Deaton, A., 1988, Quality, Quantity, and Spatial Variation of Prices, *American Economic Review,* vol. 78, 3, June, 418-430.

De Vany, A., 1973, The Revealed Value of Time in Air Travel, *Review of Economics and Statistics*, February, vol. 56, 1, 77-82.

Gardes, F., 2014, Full price elasticities and the opportunity cost for time: a Tribute to the Beckerian model of the allocation of time." *w.p. CES n° 2014-14, PSE, University Paris I*.

Gardes, F., 2016, The estimation of price elasticities and the value of time in a domestic framework: an application on French micro-data, under revision in the *Annals of Economics and Statistics*.

Gardes, F., 2017, A test of rationality axioms with individual prices in a domestic production framework, *w.p. CES n° 2017, PSE, University Paris I*.

Gardes, F., Duncan, G.J., Gaubert, P., Gurgand, M., Starzec, C., "A Comparison of Consumption Laws Estimated on American and Polish Panel and Pseudo-Panel Data", *Journal of Business and Economic Statistics* 23, 2 (2005), 242-253.

Gardes, F., Langlois, S., and Richaudeau, D. (1996), Cross-Section versus Time-Series Income Elasticities," *Economics Letters*, 51, 169-175.

Hoareau, S., Lacroix, G., Hoareau, M. and Tiberti, L. (2012) - easi: EASI Demand System Estimation. R package version 0.2.

Lewbel, A., Pendakur, K., 2009, Tricks with Hicks: The EASI Demand System, *American Economic Review, 99.3, 827-63*.

Appendix I
The estimation of the opportunity cost of time: A model of the allocation of time with an endogenous value of time

The model is fully presented in Gardes (2014, 2016).

The direct utility U depends on the consumption of final goods in quantities z_i which are produced by the household using the monetary expenditures used to buy the market goods and the time used for the corresponding activity (for instance transportation). Cobb Douglas specifications for the utility and the domestic production functions are chosen in order to allow the calculation of the opportunity cost of time as the ratio of the marginal utilities of monetary expenditures m_i and time use t_i for each activity i. Note that all the parameters of these two functions are estimated locally (i.e. for each household in the dataset). The optimization program is (all variables correspond to a household h which index is omitted in the equations):

$$\max_{m_i,t_i} u(Z) = \prod_i a_i z_i^{\gamma_i} \; with \, z_i = b_i m_i^{\alpha_i} t_i^{\beta_i} \quad \text{(A1)}$$

under the full income constraint:

$$\sum_i (m_i + \omega t_i) = w t_w + \omega (T - t_w) + V \qquad \text{(A2)}$$

with ω the valuation of time in the domestic production $T - t_w = \sum_i t_i = T_d$, w the wage rate, $wt_w$the household's wage and V other monetary incomes. Note that the opportunity cost of time ω may differ from the market wage w whenever there exist some imperfection on the labor market or if the disutility of labor is smaller for domestic production.

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

$$u(Z_i) = \prod_i a_i Z_i^{\gamma_i} = \prod_i a_i b_i \left[\prod_i m_i^{\frac{\alpha_i\gamma_i}{\sum \alpha_i\gamma_i}}\right]^{\sum \alpha_i\gamma_i} \left[\prod_i t_i^{\frac{\beta_i\gamma_i}{\sum \beta_i\gamma_i}}\right]^{\sum \beta_i\gamma_i} = a m'^{\sum \alpha_i\gamma_i} t'^{\sum \beta_i\gamma_i} \qquad \text{(A3)}$$

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 income Y and total leisure and domestic production time T_d gives the opportunity cost of time :

$$\omega = \frac{\frac{\partial u}{\partial T_d}}{\frac{\partial u}{\partial Y}} = \frac{\frac{\partial u}{\partial t'}\frac{\partial t'}{\partial T_d}}{\frac{\partial u}{\partial m'}\frac{\partial m'}{\partial Y}} = \frac{m' \sum \beta_i\gamma_i}{t' \sum \alpha_i\gamma_i} \frac{\frac{\partial t'}{\partial T_d}}{\frac{\partial m'}{\partial Y}} = \frac{\sum \beta_i\gamma_i}{\sum \alpha_i\gamma_i} \frac{T_d El_{t'/T_d}}{Y El_{m'/Y}} \qquad \text{(A4)}$$

The parameters of the utility (γ_i) and domestic production functions (α_i, β_i) are derived by the substitutions, first between time and money resources for the production of some activity, second between money expenditures (or equivalently time expenditures) concerning two different activities. These substitutions imply the system of equations:

$$m_i\gamma_j = m_j\gamma_i + \omega\gamma_i t_j - \omega\gamma_j t_i \qquad \text{(A5)}$$

which is estimated 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 γ_j. The resulting estimates of the opportunity cost of time ω and the parameters γ_j of the utility function are then used to calculate α_i and β_i for each household, and finally the opportunity cost of time ω_h for each household in the population by equation (A4). These individual values of ω_h are finally used to value time and calculate the full expenditures and the proxies to full prices.

Appendix II
Description of the dataset

The Polish Family Budget Survey panel 1997-2000

Household budget surveys have been conducted in Poland for many years. In the period analyzed, the annual total sample size was about 30 thousand households, which represent approximately 0.3% of all households in Poland. The data were collected by a rotation method on a quarterly basis. The master sample consists of households and persons living in randomly selected dwellings. This was generated by, a two-stage, and in the second stage, two-phase sampling procedure. The full description of the master sample generating procedure is given by Kordos and Kubiczek (1991).

Master samples for each year contain data from four different sub-samples. Two sub-samples started to be surveyed in 1996 and finished the four-year survey period in 2000. They were replaced by new sub-samples in 2000. Another two sub-samples of the same size were started in 1997 and followed through 2000. Over this four years period on every annual sub-sample it is possible to identify households participating in the surveys during all four years. The checked and tested number of households is 3052. The available information is as detailed as in the cross-section surveys: the usual socio-economic characteristics of households and individuals, as well as information on income and expenditures. A large part of this panel, containing demographic and income variables, is included in the comparable international data base of panels in the framework of the PACO project (Luxembourg) and is publicly available.

Prices and price indices are those reported by the Polish Statistical Office (GUS) for main expenditure items. They are observed quarterly and differentiated by 4 social categories: *workers, retired, farmers, and dual activity persons (farmers and workers).* This distinction implicitly covers the geographical distribution: workers and the retired live mostly in large and average size cities, farmers live in the countryside and dual activity persons live mostly in the countryside and in small towns. For food, price variations are taken into account at the individual observation level.

The period 1997-2000 covered by the Polish panel is the second panel covers years 1997 to 2000 corresponding to the beginning of post transition period in Poland.

The Time use survey 2003-2004

The Time Use Survey conducted in 2003-2004 is the fourth study on this subject matter in the history of the National Statistical Office (pol. GUS) and, at the same time, the first one executed in cooperation with Eurostat. The previous ones took place in the following years: 1968, 1976, 1984. They reflect the image of time management in the society of those years, however, due to methodological and organizational differences their results are difficult to compare.

Considering the usefulness of the Time Use Survey, it should be noted that time is often "a product" more in deficit than money, and its use affects many spheres of family, personal and professional life, and is also reflected, in the macro scale, in economic processes and social issues. Time management applies not only to professional work, ways of spending free time, activity in the family, non-profit work, but also such issues as the efficiency of public transport and transport network systems, participation in culture, education, sport or leisure activities. It is extremely important to obtain the knowledge about time management in territorial sections, both regional and class of locality, since many of the observed behaviours and practices concerning time management may be strongly conditioned territorially. It is also vital to obtain the knowledge about time management for various age groups or levels of education. Hence, the results of the Time Use Survey are utilized in different ways. They are the source of basic measures of level and of life quality of the population, information helpful when taking up activities regarding social policy and labour market. They are used to evaluate the value of working time in a household, they are helpful in estimating for national accounts and in preparing a national working time balance, there are of practical use, for instance, in judicial decisions or when designing laws relating to pension plans and insurance for people dealing with homework, they are also used in order to analyze territorial differences in Poland, as well as international comparisons.

The Time Use Survey in 2003-2004 was conducted on a representative sample of about 10000 households and 20000 persons. It covered persons aged 10 and more being members of selected households. Duration of the survey amounted to 365 days. Selected households conducted the survey for two days, i.e. one weekday (Monday-Friday) and one the week-end day (Saturday or Sunday). The respondents recorded performed activities, main and secondary, describing them freely in fixed 10-minute time intervals, entering persons accompanying them when they were performing those activities and the place of performing of them or the means of transport. Main and secondary activities, recorded by the respondent were then coded according to list of codes developed on the basis of *"Harmonized European Time Use Survey Guidelines"* by adequately trained persons.

The activities recorded by the respondents found their place in the following basic groups:

1. Personal care
2. Employment
3. Study
4. Household and family care
5. Voluntary work in organizations and outside them; helping others, involvement in the activities of an organization and religious practices
6. Social life and entertainment
7. Sport and outdoor activities
8. Hobbies and games – hobbies and using the computer
9. Mass media
10. Travel
11. Unspecified time use.

The study covered the main and secondary activities, a subjective assessment of the time as pleasant or unpleasant, the place of activities and people accompanying the respondent when performing the activities. Moreover, data making it possible to characterise the respondents and their households were collected.

Matching methodology

We use a dataset which combines at the individual level the monetary and time expenditures into a common, unique good and services consumption structure by a statistical match of the information contained in two surveys: Family Budget Survey Panel (FBSP, 1997-2000, (GUS) and Time Use Survey (TUS,GUS 2003). This rather difficult exercise needs some arbitrary assumptions about the substitution between time use and monetary expenditures (see Gronau and Hammermesh, 2006 for a discussion).

We define 8 types of activities or time use types compatible with the available data both from FBSP and TUS for instance for eating wich combine *Eating and cooking time* (FTB) and *food consumption* (FES). Other activities correspond to housing, clothing, transport, education, health, leisure and various consumptions. As the needed information is present only into two separate data sources (FBSP and TUS) we need to combine them. The statistical matching between the surveys was done. In this article the statistical match is done regressing the times for each activity over a common set of socio-economic characteristics of households which are present in both surveys. The estimated coefficients are used to predict these times for each household in the all four waves of the Family Budget Survey Panel.

The main methodological issue of the aggregation of time use and monetary expenditures is the estimation of the monetary value of the time spent on different domestic activities. The alternative costs of work at home can be obtained in two ways: (i) by multiplying the time spent on a given activity by the regional labour market price of work for the similar market activities or (ii) by multiplying domestic work time by the potential earnings (*opportunity costs*) which can be obtained by the given person on the labour market. The first (i) solution is certainly more precise than the second (ii), but needs detailed information on local market hourly wages for all equivalents of domestic production activities, which are rarely available (see for example Havrylyshyn,1976, Goldschmidt-Clermont, 1993).

Two methods have been used in this article to value the time spent on domestic activities. First, this value is simply the official minimum wage rate for this period in Poland, which is supposed to indicate the market wage for a low productive job. In the second method, when the time use is supposed to be perfectly exchangeable between market and non-market activities, the *opportunity cost* of non-market work is computed as the average actual net wage rates for all working individuals in the family, or by their expected hourly wage rate on the labor market for not working individuals (estimated separately for man and woman using the two-steps Heckman7 method). In the individually matched sample the total value of non monetary activities can be obtained directly by adding man's and woman's contributions. Both evaluation methods are adjusted for income taxes and the estimated numbers of working days and hours.

Appendix III
Results

Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
foodm97	3052	548.2228	250.0745	38.05	2644.08
housingm97	3052	276.4957	514.1657	5	18279.85
clothingm97	3052	112.1347	130.983	.3	1518.17
transpcom97	3052	158.2667	591.3021	.4	17801.57
leisurem97	3052	93.3945	169.3334	.7	3501.7
otherm97	3052	152.0203	172.867	5.8	4086.99
depm97	3052	1340.535	994.8333	292.24	20363.52

Variable	Obs	Mean	Std. Dev.	Min	Max
foodf97om	3052	665.0616	253.5243	117.6028	2837.026
housingf97om	3052	300.4666	516.3727	28.76148	18363.4
clothing~7om	3052	117.21	130.9311	1.706277	1522.646
transpco~7om	3052	203.4781	591.1573	41.52517	17854.43
leisuref97om	3052	258.23	173.4382	94.51119	3663.499
otherf97om	3052	206.2381	171.8458	69.03389	4160.602
yf97om	3052	1501.98	865.228	532.488	17851.49

Estimation on sub-population of rational or non-rational households

1. Estimation on all households

PREDICTED SHARES, BUDGET AND (UN)COMPENSATED OWN-PRICE ELASTICITIES

	shares b/se	budget b/se	u_price b/se	c_price b/se
wfoodom97	0.402***	0.674***	-2.605***	-2.335***
	(0.026)	(0.029)	(0.097)	(0.124)
whousin~97	0.153***	1.752***	-2.763***	-2.495***
	(0.023)	(0.135)	(0.249)	(0.269)
wtransp~97	0.101***	1.454***	-1.021***	-0.875***
	(0.009)	(0.097)	(0.034)	(0.036)
wclothi~97	0.066***	1.288***	-1.065***	-0.980***
	(0.004)	(0.151)	(0.025)	(0.031)
wleisur~97	0.155***	0.840***	-1.232***	-1.102***
	(0.006)	(0.136)	(0.025)	(0.010)
wotherom97	0.124***	0.803***	-2.130***	-2.031***
	(0.004)	(0.205)	(0.047)	(0.065)

* p<0.05, ** p<0.01, *** p<0.001

2. Estimation on households not violating the weak and strong axioms

PREDICTED SHARES, BUDGET AND (UN)COMPENSATED OWN-PRICE ELASTICITIES

	shares b/se	budget b/se	u_price b/se	c_price b/se
wfoodom97	0.402***	0.661***	-2.907***	-2.642***
	(0.030)	(0.034)	(0.137)	(0.169)
whousin~97	0.154***	1.712***	-3.068***	-2.805***
	(0.024)	(0.138)	(0.315)	(0.337)
wtransp~97	0.100***	1.461***	-1.014***	-0.868***
	(0.011)	(0.107)	(0.049)	(0.051)
wclothi~97	0.066***	1.406***	-1.080***	-0.987***
	(0.006)	(0.133)	(0.039)	(0.047)
wleisur~97	0.155***	0.882***	-1.243***	-1.106***
	(0.004)	(0.157)	(0.019)	(0.008)
wotherom97	0.124***	0.776***	-2.330***	-2.234***
	(0.006)	(0.215)	(0.079)	(0.103)

* p<0.05, ** p<0.01, *** p<0.001

3. Estimation on all households violating the weak and strong axioms

PREDICTED SHARES, BUDGET AND (UN)COMPENSATED OWN-PRICE ELASTICITIES

	shares b/se	budget b/se	u_price b/se	c_price b/se
wfoodom97	0.410***	0.698***	-2.086***	-1.799***
	(0.066)	(0.074)	(0.159)	(0.227)
whousin~97	0.163*	1.895***	-2.258***	-1.950**
	(0.079)	(0.501)	(0.573)	(0.645)
wtransp~97	0.090***	1.488***	-0.989***	-0.856***
	(0.025)	(0.332)	(0.078)	(0.093)
wclothi~97	0.059***	0.937	-0.989***	-0.934***
	(0.006)	(0.666)	(0.046)	(0.031)
wleisur~97	0.157***	0.742*	-1.186***	-1.070***
	(0.028)	(0.334)	(0.117)	(0.086)
wotherom97	0.122***	0.823	-1.815***	-1.715***
	(0.008)	(0.691)	(0.104)	(0.095)

* p<0.05, ** p<0.01, *** p<0.001