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**A Method to infer time preference from the value of time**

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# A Method to infer time preference from the value of time

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## Abstract

Using a generalization of Becker's time allocation model in order to estimate the shadow price of time, we explore the relationship between the inter-temporal substitution rate and the opportunity cost of time, allowing the endogenization of the time preference from the estimation of the value of time.

**Keywords:** Time Allocation, Inter-temporal substitution rate, psychological rate of interest, Opportunity cost of time.

**JEL:** D31, J22.

## Introduction

Actualizing the future supposes the definition of an intertemporal substitution rate (ITSR) which is generally calibrated by reference to the capital market or to an anticipated rate of return for public investments when considering public expenditures. That actualization rate is

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often fixed at the average long term growth rate of the economy (see the discussion in Sunstein, 2014, pp. 62-63). Independently from this intertemporal rate, households value their disposable time by some opportunity cost of time which influences their decisions for market work and domestic production. A natural idea is that there may exist some relationship between these valuations of present and future time, but it seems that no model exists up to now exploring that link. It can be expected that an exogenous increase of the value of time may accelerate monetary expenses by way of substitution with time use in home production, which could develop the preference for present money over future money, thus increasing the psychological rate of interest. This article explores a relationship between these parameters based on the assumption of a constant household's permanent wealth. Other possible ways to define this relation, either considering the saving and present consumption decisions, or by means of the utility changes attached to postponing some expenditure, are discussed in Gardes (2021b).

In order to estimate the opportunity cost of time, I use a home production model (presented in Appendix A) where the consumer combines time with market goods to produce activities that generate utility. Utility maximization implies that the value of time is given by the ratio of the marginal utility of time over the marginal utility of income. Previous papers (Gardes 2018 and 2019, Canelas et al. 2018) show that this ratio can be structurally estimated at the individual level provided that data on households' time and monetary expenditures are available. To overcome the lack of this type of data, I combine, using a statistical matching procedure described in Appendix B, a french survey on household expenditures with a survey on time use made in the same year (2000).

Section 1 describes the estimation of the opportunity cost of time while section 2 presents the relation between the intertemporal rate and the opportunity cost of time. Section 3 applies the model to the french dataset.

# I Estimation of the proportion of substituable chores

## Two indicators of full income

### Two indicators of full income

The usual full income concept  $y_0^f$  is the maximum monetary income which could be earned when working during all disposable time  $T$ , valued at the market wage rate net of taxes  $W$ :

$$y_0^f = WT + V. \quad (1)$$

with  $V$  other incomes unrelated to market work (financial revenues, social distribution...). Another indicator of household's full resources, adding the opportunity cost of domestic production to monetary income from market work and other sources, can be defined, first valuing the time used in home production by the estimated opportunity cost and second, considering that only a part of domestic production could be afforded by market goods and services. The non-substituable component of domestic production (speaking with one's spouse for instance) would not be added to the full estimate of household's resources. Indicating by  $\pi_i$  the proportion of home product  $i$  which can be replaced by a market product or service, this indicator of full resources writes:

$$y^f = Wt_w + V + \omega \sum \pi_i t_i. \quad (2)$$

The next section proposes a method to calculate these proportions  $\pi_i$ .

### Substituable chores

Chores (domestic daily works) are generally defined as the minimum amount of home production the value of which could be added to the value of the agent's production working on the labor market. Pure leisure activity would for instance be excluded. Home production related to food would be considered as a chore only if it corresponds to the normal amount of food for a typical similar agent, the individual surplus of a given agent being considered as linked

to its particular constraints or preferences to be excluded from the chores. But this minimum amount is difficult to estimate, either directly on a survey (choosing for instance the first tercile of the distribution of time use for food among similar individuals) or by estimation of a demand system such as the Linear Expenditures System.

I propose a new method estimating the proportion of time devoted to some home activity which can be considered as a chore, by means of the degree of substitution with market alternative goods or services: the value of chores for a given domestic production (for instance of transport) is the cost to acquire a substitute on the market. The integration of that value in the market production thus proceeds from the possibility to obtain the same final good on the market at a given price which is attributed to that component of the domestic production. This requires that the elasticity of substitution between market factors of production and time must be large, so that it is possible to produce the same amount of final good with these market factors substituted to time use.

Suppose that the domestic production of some final good  $i$  is divided between 'substituable' chores 1 produced under possible substitutability with market goods or services (supposed to be governed by a unitary elasticity of substitution between monetary and time inputs, corresponding to a Cobb-Douglas domestic production function:  $: El_{t_{i,1}/\omega} = 1$ ) and non-substituable chores 2 characterized by a zero elasticity of substitution with market goods ( $\frac{\delta[(t_{i,1})/m_i]}{\delta(\omega)} = 0$ ). The same division applies to the total time devoted to the home production of the final good:  $t_i = t_{i,1} + t_{i,2}$ , with  $t_{i,1}$  and  $t_{i,2}$  the times spent in substituable (respectively non-substituable) home work producing the final good  $i$ . The elasticity of substitution of the aggregate time  $t_i$  over the opportunity cost of time  $\omega$  writes, with  $m_i$  the expenditure made for market goods and services used producing the final good:

$$\sigma_i = \frac{\frac{\delta[(t_{i,1}+t_{i,2})/m_i]}{\delta(\omega)}}{[(t_{i,1} + t_{i,2})/m_i]/\omega} = \frac{\frac{\delta[t_{i,1}/m_i]}{\delta(\omega)}}{(t_{i,1}/m_i)/\omega} \frac{t_{i,1}}{(t_{i,1} + t_{i,2})} = \sigma_{i,1} \frac{t_{i,1}}{t_{i,1} + t_{i,2}} = -\frac{t_{i,1}}{t_{i,1} + t_{i,2}} = -\pi_i \quad (3)$$

The proportion of chores in this domestic activity can then be measured by the absolute value of the elasticity of substitution of the aggregate, the absolute value of which is smaller than one for all activities in our french dataset : 0.36 for food, 0.30 for clothing, 0.66 for leisure activities, 0.30 for All Other activities (see Canelas et al., 2018). The total value of chores  $v_i$  in each domestic activity will be calculated by means of these elasticities of substitution and added to the monetary value of expenditures made to produce the corresponding final good:  $v_i = \omega_i.t_{i,1} = |\sigma_i|. \omega_i.t_i$ . A generalization to the case of multiple components of chores with different elasticities of substitution is straightforward.

The household's full resources are therefore the sum of monetary income and of that component of substituable chores valued by the estimated opportunity cost of the household:

$$y^f = Wt_w + V - \omega \sum \sigma_i t_i = Wt_w + V + \omega |\sigma| (T - t_w) \quad (4)$$

with  $\sigma$  the weighted average (weighted by the time budget shares) of the elasticities of substitution  $\sigma_i$ . The permanent income is estimated at the households' level, then aggregated over the population.

## II Relating time preference to the value of time

A natural relation between  $\rho$  and  $\omega$  can be extracted from their complementary relations with the household's saving rate, since the value of time impacts the household's consumption and labor income, while the rate of interest impacts its saving rate. In this first model, the household's time preference determines its saving rate, while the value of time is correlated with its expenditures, so that it could be possible to establish a relationship between them equalizing the values of its household's savings depending on these two variables. The calculus implies a positive relationship between the intertemporal rate and the value of time. This model relies on the assumption that the decision to save part of income is taken in relation with an interest rate independently from the marginal propensity to consume, which is a heroic hypothesis whence it applies to one agent (while it is more naturally applied to aggregates in the simple keynesian

model). Another way to obtain a relation between  $\rho$  and  $\omega$  relies on the maximization of a utility depending both on monetary and time expenditures, but this needs specifying a particular utility and estimating its coefficients<sup>1</sup>.

The more general method we propose relies on the assumption that the ITSR and the opportunity cost of time both influence the present value of the household's permanent full income (equal to the discounted sum of all future full incomes  $y^f$ <sup>2</sup>). Following the assumption made in the permanent income theory, the present value of the stream of future full incomes is supposed to remain constant over the household's life cycle, in spite of changes in the opportunity cost of time due to age, family structure or income. This supposes that the inter-temporal rate of substitution varies accordingly to the opportunity cost of time in order to maintain the permanent income constant through the life cycle, in spite of changes in the opportunity cost of time due to age, family structure or income (all being supposed to be anticipated by the household). Therefore, it is possible to calculate the change between two consecutive periods of the intertemporal rate of substitution which corresponds to a change in the opportunity cost of time. The present value of the permanent income stream can be written for the full income flow  $y^f$  and an ISTR  $\rho$ :

$$v(y^f) = \int [y_t^f \exp(-\rho t)] dt \quad (5)$$

The derivative over  $\omega$  of this integral equals, under usual conditions, the integral of the derivative of the full income  $y^f$ , which is, with  $\rho$  depending on  $\omega$ :

$$\phi = \frac{\partial y^f}{\partial \omega} = W \frac{\partial t_W}{\partial \omega} + (T - t_W) - \omega \frac{\partial t_W}{\partial \omega} = \left( \frac{W}{\omega} - 1 \right) E_{t_W} + \sum |\sigma_i| t_i \quad (6)$$

The integration over time (from 0 to infinity<sup>3</sup>) of this derivative is equal to zero since permanent full income remains constant:

<sup>1</sup>The calculus for these methods are presented in Gardes, 2021b.

<sup>2</sup>A model restricted to two periods is presented in Gardes, 2021b.

<sup>3</sup>Households are supposed to leave their permanent wealth to their inheritants. Considering the life cycle from birth to age T multiplies the derivative of  $\rho$  over  $\omega$  by the fraction  $\frac{\exp(-\rho T)-1}{\rho \exp(-\rho T)} \left( T + \frac{1}{\rho} \right) - 1$  which is for instance 0.925 for  $\rho = 5\%$  and T=80 years (corresponding to the average life duration in developed countries) or 0.418 for T=20 (corresponding to an evaluation at age 60 till 80).



$$\int \left\{ \frac{\partial y_t^f}{\partial \omega} \right\} \exp(-\rho t) dt = \frac{\phi}{\rho} - y_t^f \frac{1}{\rho^2} \frac{\partial \rho}{\partial \omega} = 0 \quad (7)$$

Under the assumption that the household's permanent income does not change for corresponding changes of the intertemporal rate and the opportunity cost ( $d\rho, d\omega$ ), the marginal propensity and the elasticity of the ITSR over the opportunity cost of time are:

$$\frac{\partial \rho}{\partial \omega} = \frac{\left(\frac{W}{\omega} - 1\right) t_W El_{t_W} + \sum |\sigma_i| t_i}{W t_W + V + \omega \sum |\sigma_i| t_i} \rho \quad (8)$$

$$El_{\frac{\rho}{\omega}} = \frac{(W - \omega) t_W El_{t_W} + \omega \sum |\sigma_i| t_i}{W t_W + V + \omega \sum |\sigma_i| t_i} \quad (9)$$

Therefore, the ISTR increases with the opportunity cost of time with an elasticity positive and smaller than 1 whence  $V \geq 0$ ,  $El_{t_W} \leq 1$  and  $W \geq \omega$ . It may vary between households, which implies different intertemporal rates across the population, and may depend on macroeconomic conditions changing the households' wage rates, their opportunity cost of time, the allocation of time between market work and home production and the elasticity of market work supply.

### III Empirical Results

The only parameter which must be estimated in equations (11) and (12) is the elasticity of market labor over the opportunity cost. Market labor time can be considered as the residual of domestic production time over the total disposable time  $T$  (supposed to be exogenous), so that this elasticity can be estimated by means of the elasticities of domestic production times  $t_i$  over the opportunity cost of time  $\omega$ . Estimation of that elasticity of the market labor time using the french dataset (Gardes and Margolis, 2014) provides an estimate 0.861 for the whole population, with significant changes for different sub-populations, as indicated in Gardes and Margolis, Table 1. A direct estimation of the regression between  $T - \sum t_i$  and  $\rho$ , reported in Table 1, gives positive but smaller estimates which are more in line with the usual estimations of the elasticity of market work over the wage rate. These estimations are used in the calculus

of the marginal propensity and the elasticity of  $\rho$  over  $\omega$ <sup>4</sup>

On the french dataset, equation (11) gives a derivative of  $\rho$  over  $\omega$  equal to 0.00221 for the whole population and an elasticity  $El_{\frac{\rho}{\omega}} = 0.246$ <sup>5</sup>. It can be concluded that the intertemporal rate of substitution  $\rho$  increases with the opportunity cost of time  $\omega$ , with an elasticity which is smaller than one. These parameters change a lot on sub-populations : results in Table 1, in accordance with other studies (Gardes, 2019, 2020), show that the opportunity cost of time is greater for households having a more constrained time budget (families with children, middle aged households) and much smaller for singles<sup>6</sup>. The elasticity of market work over the opportunity cost of time diminishes with age and is larger for families with children, while the elasticity of the inter-temporal rate of substitution over the opportunity cost of time increases with age and the presence of children and is one half smaller for singles compared to families with children. This shows that the effect of the value of domestic time over the rate of substitution differs much across the population. The resulting change of the inter-temporal substitution rate due to income (in the cross-section dimension) is a relative increase by one third to two thirds from the 5th centile to the 95th centile of the income distribution (for instance from 3.77% to 6.23% for families with children, which corresponds to a cumulated actualized full income over the life cycle equal to 26.5 times the yearly income for 3.77% and only 16.0 for 6.23%). Therefore, the increase of yearly full income has a proportional positive direct effect on the cumulated income over the life cycle, but also a negative indirect effect through the increase of the inter-temporal substitution rate: for instance, an increase of yearly income (over the whole life cycle) by +10% increases the ISTR supposed at its mean 5%) by 0.114% , which implies a reduced total positive effect +7.7%.

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<sup>4</sup>Estimates using the higher elasticities of market work obtained by the indirect method based on domestic work in Gardes and Margolis are not so different.

<sup>5</sup>In this estimation, the domestic times are reduced by a factor  $|\sigma_i|$  which measures the component in the domestic activity  $i$  which can be substituted to market goods and services as discussed in the previous sub-section. Computed on total domestic times, the corresponding  $\frac{\partial \rho}{\partial \omega} = 0.00559(0.00237)$  is doubled.

<sup>6</sup>This can be explained by the different time budget constraints of these households' types.

TABLE 1  
Derivative of  $\rho$  over  $\omega$  and Elasticity

	$\omega$	$El_{\frac{W}{\omega}}$	$\frac{\partial \rho}{\partial \omega}$	$El_{\frac{\rho}{\omega}}$	$\rho^{5^{th}}(\%)$	$\rho^{95^{th}}(\%)$
Whole Population	6.23	0.281	0.00221	0.246	4.26	5.74
s.e.	2.02	0.017	0.00197	0.171	-	-
Singles	5.82	0.093	0.00184	0.184	4.53	5.47
s.e.	1.56	0.035	0.00145	0.126	-	-
Couples without children	6.23	0.213	0.00222	0.265	4.14	5.86
s.e.	2.36	0.027	0.00179	0.148	-	-
Couples with children	6.62	0.356	0.00279	0.338	3.77	6.23
s.e.	1.87	0.031	0.00143	0.126	-	-
Age till 35	6.02	0.413	0.00174	0.194	4.50	5.50
s.e.	1.73	0.036	0.00329	0.307	-	-
Age 36-55	6.46	0.268	0.00223	0.250	4.16	5.84
s.e.	2.30	0.019	0.00157	0.122	-	-
Age after 56	6.09	0.127	0.00321	0.358	4.04	5.86
s.e.	1.81	0.065	0.00203	0.182	-	-

Note: Bootstrap standard errors. Direct estimation of  $El_{\frac{W}{\omega}}$  on the dataset.  $\rho^{5^{th}}$ : estimate of  $\rho$  in the fifth quintile of the income distribution.

## IV Conclusion

This paper provides an estimate of the intertemporal substitution rate depending on the value of time experienced by the household. This relation serves as an endogeneisation of the psychological intertemporal rate which is generally supposed to be the same for all households and which is calibrated at an a priori amount which is rarely justified by some reasoning. It gives also a microeconomic explanation of the level of the primary interest rate central to the austrian school (see von Mises, 1949, chapters 18 and 19) and articles by Garrison, Fetter, Herbener, Kirzner and Rothbard in Herbener ed., 2011). The empirical analysis of individual data shows that this psychological rate of interest is positively correlated to the value of time, depends on the elasticity of market labor over the value of time and varies significantly across the population. This relationship between time preference and the value of time have been used in Gardes (2021a) in order to estimate an enlarged GDP including domestic production and to discuss the Austrian trade cycle theory (Gardes, 2021c)

## Appendix A: Estimation of the opportunity cost of time<sup>7</sup>

In order to estimate the shadow price of time, I assume that the consumer combines time with monetary expenditures to produce activities that generate utility in a model where the market working time is valued by the consumer's wage rate while the remaining time (e.g., time allocated to leisure or non-market work) is valued by a shadow price of time that may differ from the wage rate. It is assumed that the consumer's utility function is given by  $u(z) = \prod_i a_i z_i^{\gamma_i}$  where  $a_i$  is a positive parameter and  $z_i$  is the quantity of the activity  $i$  produced by the combination of monetary and time inputs denoted  $m_i$  and  $t_i$ , respectively:  $z_i = b_i m_i^{\alpha_i} t_i^{\beta_i}$  where  $m_i = x_i p_i$  with  $x_i$  the quantity of the market goods  $i$ ,  $p_i$  its monetary price, and  $b_i$  a positive parameter<sup>8</sup>.

Contrary to the complementarity structure of domestic production functions in Becker's model of the allocation of time (1965), the choice of the Cobb-Douglas forms allows the parameters to be identifiable assuming that  $\alpha_i + \beta_i = 1$  (no economy of scale in the domestic productions). As we estimate the parameters locally (i.e., for each observation in the dataset), the Cobb-Douglas specifications imply simply constant substitution between time and monetary resources only in the neighborhood of each individual's equilibrium point. As discussed in Gardes (2019), the Cobb-Douglas specification allows identifying a unique shadow price of time for all activities while a more general model based on CES household production functions allows identifying activity-specific shadow prices of time together with an average value of domestic time.

Combining the utility and the production functions allows to write the utility in terms of inputs:

$$u(m, t) = \prod_i (a_i b_i^{\gamma_i}) \left( \prod_i m_i^{\frac{\alpha_i \gamma_i}{\sum \alpha_i \gamma_i}} \right)^{\sum \alpha_i \gamma_i} \left( \prod_i t_i^{\frac{\beta_i \gamma_i}{\sum \beta_i \gamma_i}} \right)^{\sum \beta_i \gamma_i} \quad (10)$$

$$= A m'^{\sum \alpha_i \gamma_i} t'^{\sum \beta_i \gamma_i} \quad (11)$$

where  $m'$  and  $t'$  are geometric weighted means of the monetary and time inputs and  $A \equiv \prod_i a_i b_i^{\gamma_i}$ .

<sup>7</sup>From Gardes, 2019.

<sup>8</sup> $z$  is assumed to depend on  $m$  (rather than  $x$ ) because the dataset informs only expenditures. This approach yields consistent results when all households face the same prices.

In this framework, the consumer is subject to an income constraint,  $\sum m_i = wt_w + V \equiv Y$ , and to a time constraint,  $\sum_i t_i + t_w = T$ , where  $V$  is other income,  $t_w$  is the time allocated to market work and  $T$  total disposable time<sup>9</sup>. Utility maximization implies that the shadow price of time, denoted  $\omega$ , is given by:

$$\omega = \frac{\frac{\partial u}{\partial t'} \frac{\partial t'}{\partial (\sum t_i)}}{\frac{\partial u}{\partial m'} \frac{\partial m'}{\partial Y}} = \frac{m' \sum \beta_i \gamma_i \frac{\partial t'}{\partial (\sum t_i)}}{t' \sum \alpha_i \gamma_i \frac{\partial m'}{\partial Y}} \quad (12)$$

The shadow price of time differs from the market wage rate when, for instance, there exist some market imperfections, transaction costs, and constraints on the labor market or in the home sector. The shadow price of time can be estimated provided that estimates of  $\alpha_i$ ,  $\beta_i$ , and  $\gamma_i$  are available, which is obtained considering the substitutions between monetary and time expenditures in the production of each final goods and by the substitution of time or money between activities (see details in Gardes 2019).

## Appendix B: Datasets

In order to dispose of households' monetary expenditures and time uses, 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).

The definition of comparable good and time groups of expenditure is a difficult and sometimes arbitrary operation. This rather difficult exercise needs some arbitrary assumptions about the substitution between time use and monetary expenditures (see Gronau and Hamermesh 2006 for a discussion). The commodity consumption structure does not correspond exactly to what is often used as a standard classification of time uses even if differences can be limited. The reason is that not all time use activities can have a clear work equivalent. This is particularly the case of the leisure time. However, comparing our classification with other similar approaches

<sup>9</sup>Excluding sleeping time, although, as remarked by Aguiar and Hurst (2007), 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.

TABLE 2  
Descriptive statistics

	$\sigma$ food	$\sigma$ non-food	$El_{\frac{t_w}{\omega}}$	t food	t non-food	$t_w$	W
Whole Population	0.620	0.692	0.861	31.0	101.1	56.3	10.13
s.e.	0.017	0.009	0.0038	13.6	32.4	24.9	15.87
Singles	0.685	0.741	1.336	18.1	67.6	38.5	9.04
s.e.	0.047	0.023	0.0116	7.1	15.6	13.3	5.80
Couples without children	0.558	0.644	1.043	39.1	122.4	59.5	10.92
s.e.	0.022	0.011	0.0096	13.5	29.7	26.1	22.35
Couples with children	0.905	1.097	0.590	33.3	106.4	62.5	10.10
s.e.	0.034	0.017	0.064	8.4	18.9	24.3	13.6
Age till 35	0.619	0.902	-	21.4	91.3	57.4	7.72
s.e.	0.063	0.030	-	9.9	28.5	24.3	3.77
Age 36-55	0.596	0.711	-	29.6	93.0	57.4	10.67
s.e.	0.023	0.012	-	11.1	27.3	24.5	10.8
Age after 56	0.764	0.768	-	37.9	115.4	46.8	13.64
s.e.	0.029	0.014	-	14.23	34.37	26.5	39.88

Note:  $\sigma$ : elasticity of substitution between monetary expenditures and time uses; t: time use per week;  $t_w$ : market work time; W: household's average wage rate;  $El_{\frac{t_w}{\omega}}$ : elasticity of the labor supply over the opportunity cost of time;  $\frac{\partial p}{\partial \omega}$  (respectively  $El_p$ ): marginal propensity (respectively elasticity) of the intertemporal rate of substitution over the value of time using estimates in Canelas et al. (2018).

(Gronau and Hamermesh, 2006) we obtain similar patterns of what these authors call "relative goods/time intensity" defined as a ratio of good to time inputs relative to total amount of goods and time allocated to the production of final goods.

The French dataset from INSEE 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 households' characteristics using common covariates observed in the two surveys (such as education level and the age of the head, the family demographic structure and location) for all observation units in the FTB survey and these estimations serve to predict the time spent on these activities for the corresponding units in the FES survey.

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