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Documents de Travail du
Centre d'Economie de la Sorbonne

CES Working Papers

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UMR 8174

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2021.24

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https://centredeconomiesorbonne.cnrs.fr/
ISSN : 1955-611X

A SOLUTION TO THE ESTIMATION OF AN ENLARGED GDP INCLUDING DOMESTIC PRODUCTION: AN ESTIMATION ON MICRO DATA

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March 23, 2021

Abstract

Using a generalization of the Becker's time allocation model to estimate the shadow price of time, the article proposes to evaluate the component of home production which could be substituted by market goods and services. An enlarged households' total expenditure including the production of the informal sector and the value of domestic production and the corresponding enlarged GDP are compared to their monetary counterparts in five developed and under-developed countries. Domestic production substituable to market goods corresponds to 23 to 41% of the GDP in Canada, France, Poland and the US, but much less in Burkina Faso because of much lower opportunity cost of time and elasticities of substitution. Finally, the enlarged GDP including the informal sector is larger by 40% than the official GDP in the three developed countries, 34% in Poland and by 54% in Burkina Faso.

*gardes@univ-paris1.fr. A grant from the Scientific Policy of University Paris I is aknowledged. Thanks to Anil Alpman, Kristof Starzec, Philip Merrigan and *Noël* Thiombiano for their collaboration to the preparation of the datasets.

Documents de travail du Centre d'Economie de la Sorbonne - 2021.24

Keywords: Domestic Production, Time Allocation, GDP, Opportunity Cost of Time.

JEL: D31, J22.

I Introduction

The exclusion of the value of non-market activities has been raised as a serious issue since the introduction of the time allocation theory (sometimes referred to as the household production theory) by Becker (1965). Indeed, the size of the home sector is quite large (home production equals on average two-thirds of a household's total monetary income according to Gronau [1980])[1]. The Stiglitz report (2009) considers that the estimation of an enlarged GDP containing the value of the production in informal markets and the value of households' home production (together with the cost of environmental externalities) is crucial to discuss the changes of the households' well-being. The inclusion of informal markets adds generally less that 10% to the GDP in developed countries [2] and does not vary much, except during national structural changes such as those experienced in previously communist states[3]. The size of the informal sector can be captured through surveys on employment or comparing actual households' expenditures to those which are predicted by increased incomes from black markets (see Pissarides and Weber, 1989, Lyssiotou et al., 2004, or Gardes-Starzec, 2010). On the contrary, the estimation of home production needs new methods to value home production and to define precisely the type of domestic products which can be added to the market product. I propose to add to market goods only those home produced final goods which could be acquired on the market (the cake home produced but not a conversation with one's spouse).

The estimation made by Gronau (as well as Bonke, 1992, Frazis et al., 2011 and Jenkins et al., 1996) used the households' average market wage as the opportunity cost of time. Direct surveys as well as recent estimation show that this opportunity cost is rather, at an individual level, around one half of household's average wage rate and indexed on it with an rather high

[1]The full income, which includes the value of home production, is also more equally distributed than the monetary income (Frick et al., 2012; Frazis and Stewart, 2011; Bonke, 1992 Gardes-Starzec, 2018.)

[2]Only 5.2% in Canada for instance according to Fortin, Lacroix and Montmarquette, 2009, in a study based on individual data.

[3]In Poland for instance, the size of black markets increased temporally till 30% of the GDP after the liberalization of the economy in 1989.

elasticity, between one third and two third according to the country (Gardes, 2019). This usual calibration by an average (or the minimum) wage rate suffers both from its over-estimation and from its lack of relation with income, the individual wage rate or the family structure. For that purpose, we use a home production model where the consumer combines time with market goods to produce activities (final goods) that generate utility. Utility maximization implies that the value of time is given by the ratio of the marginal utility of time to the marginal utility of market goods. The method proposed by Gardes (2018, 2019) shows that this ratio can be structurally estimated provided that data on time and income are available. To overcome the lack of this type of data, individual data containing both informations at the household level are built by a matching of a Households Budget survey with a Time Use survey for the same population and period (the matching procedure is detailed in Appendix A, I).

Section 2 presents the model defining substituable chores, section 3 present the model used for the estimation of the opportunity cost of time and section 4 provides empirical results for five developed and under-developed countries. The statistical matching procedure that we use to combine the Time use survey with a Family expenditure survey and the datasets are presented in Appendix.

II Estimation of the proportion of substituable chores

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:

$$y_0^f = WT + V. \tag{1}$$

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 π_i the proportion of home product i which can be replaced by a market product or service, this indicator of full resources writes:

$$y^f = Wt_w + V + \omega \sum \pi_i t_i. \tag{2}$$

The next section proposes a method to calculate these proportions π_i.

Substituable chores

Chores (domestic dayly 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 substituability 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 ($\sigma_{i,2} = \frac{\delta[(t_{i,2})/m_i]}{\delta(\omega)} = 0$). 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 ω writes, with m_i the expenditure made for market goods and services used producing the final good:

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

The proportion of chores in this domestic activity can then be measured by the absolute value of the elasticity of substitution of the aggregate, 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:

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

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

III Estimation of the opportunity cost of time[4]

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 work 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 the shadow price of time that may differ from the wage rate. It is assumed that the consumer's utility function is given by $u(Q) = \prod_i a_i Q_i^{\gamma_i}$ where a_i is a positive parameter and Q_i is the quantity of the activity i produced by the combination of monetary and time inputs denoted m_i and t_i, respectively: $Q_i = b_i m_i^{\alpha_i} t_i^{\beta_i}$ where $m_i = x_i p_i$ with x_i the quantity of the market goods i, p_i its price, and b_i a positive parameter.[5] The choice of the Cobb-Douglas forms allows the parameters to be identifiable. 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 (2018, 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 only activity-specific shadow prices of time.

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

[4] Based on Gardes, 2019.

[5] Q 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.

inputs:

$$u(m,t) = \Pi_i (a_i b_i^{\gamma_i}) \left(\prod_i m_i^{\frac{\alpha_i \gamma_i}{\sum \alpha_i \gamma_i}} \right)^{\sum \alpha_i \gamma_i} \left(\prod_i t_i^{\frac{\beta_i \gamma_i}{\sum \beta_i \gamma_i}} \right)^{\sum \beta_i \gamma_i} \tag{5}$$

$$= A \; m'^{\sum \alpha \gamma_i} \; t'^{\sum \beta_i \gamma_i} \tag{6}$$

where m' and t' are geometric weighted means of the monetary and time inputs and $A \equiv \Pi_i a_i b_i^{\gamma_i}$. In this framework, the consumer is subject to an income constraint, $\sum m_i = w t_w + V \equiv Y$, and to a time constraint, $\sum_i t_i + t_w = T$, where V is other income and t_w is the time allocated to market work. Utility maximization implies that the shadow price of time, denoted ω, is given by

$$\omega = \frac{\frac{\partial u}{\partial t'} \frac{\partial t'}{\partial (\sum t_i)}}{\frac{\partial u}{\partial m'} \frac{\partial m'}{\partial Y}} = \frac{m' \sum \beta_i \gamma_i \frac{\partial t'}{\partial (\sum t_i)}}{t' \sum \alpha_i \gamma_i \frac{\partial m'}{\partial Y}} \tag{7}$$

The shadow price of time differs from the market wage rate when, for instance, there exists 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 α_i, β_i, and γ_i are available which is obtained by means of substitutions of monetary and time expenditures in the production of each final goods and by substitution of time or money between activities (see Gardes 2019).

IV Aggregate results for five countries

Table 1 present estimations for three developed countries (Canada, France and the US), Poland after the liberalization of the economy (in 1989) and Burkina Faso.

The value of domestic production is similar in France and the U.S. (aroud 40% of the GDP), while it is smaller in Canada and negligeable in Burkina Faso. The low proportion of domestic production in Burkina Faso procedes from a very low value of time and also a low elasticity of substitution between the factors of domestic production (-0.083)[6]. That possibility

[6]Note however that the domestic production assuming a unitary elasticity of substitution is also low in Burkina Faso, at 70, corresponding to only 10% of the GDP. On the contrary, the estimation of the full GDP in France with

TABLE 1
Enlarged GDP (Per capita value in US dollars 2015)

Country	ω	$\frac{\omega}{w}$	GDP	$\frac{Informal}{GDP}*$	Home production	Enlarged GDP	$\frac{EnlargedGDP}{GDP}$
Burkina Faso	0.098	0.30	671.7	52.6%	4.1	1029	1.53
Canada	10.93	0.69	50304	15.5%	9910	68011	1.35
France	7.01	0.52	42503	14.3%	14413	62994	1.48
Poland	4.26	0.43	12702	30.2%	3446	19984	1.57
U.S.A.	12.75	0.74	53042	9.5%	19995	78016	1.47

Note: * Hassan and Schneider (2016) estimates.

to substitute market goods and services to home production is thus a very important feature of the allocation of time by households and it generates the relative importance of domestic production in the enlarged GDP. In Canada, the opportunity cost of time has been estimated on a survey containing only family composed of two aduts without children, which would imply, as shown in other similar countries (France and the US), an under-estimation of 10 to 20% compared to the estimate on the whole population.

Finally, the enlarged GDP is larger than the GDP by 40% in the three developed countries and by 34% in Poland (because of the low level of domestic production), while it is much larger in Burkina Faso because of the extension of the informal sector.

Two results appear clearly in a dynamic study on Poland between 1997 and 2000 for which a unique Time Use survey (2003-2004) is matched with a panel of four years: the dispersion of the value of domestic production (coefficient of variation equal to 2.53) is larger than the dispersion of households' income (0.77) and expenditures (0.67). Second, the change of these resources between 1997 and 2000 shows that their evolution are not parallel, specially considering short term changes: for instance, households real income increases between 1997 and 1998 by 8.35% while the change for enlarged income (income+domestic production) is +16.99%. On the contrary, the corresponding changes between 1998 and 1999 are +8.01% vs 7.63%, and 7.92% vs 1.21% between 1999 and 2000. On the whole 1997-2000 period, the changes for income, expenditures, domestic production, Income+Domestic Production and Expenditures+Domestic Production are respectively: +26.29%, +15.95%, +28.27%, +23.16% and +27.44%. This shows that it is important to examine the amounts and evolutions of these monetary and time resources over a longer period as they can be substituable to a large extent

unitary elasticities of substitution, i.e. without the correction for the degree of substitution of home production with market goods and services, is greater by 25% in France, which shows the importance of that correction

in the short run.

The inequality of the households' home production across the population is somewhat larger than the corresponding inequality for households' income or total expenditure. Its logarithmic standard error is for instance 101.9% in Poland, while it amounts to 61.6% for households' income (45.0% for households' total expenditure) and 67.1% for their enlarged income. This inequality depends both on the volatility of the opportunity cost of time (logarithmic standard error equal to 96.5%) and on the differences in times allocated for each domestic activity. It would even be greater if the elasticities of substitution were estimated at the individual level, for each household or household type.

V Conclusion

This paper provides a method to estimate the component of households' domestic production which can be added to GDP because it corresponds to the production of commodities which could have been purchased on the market. The definition of these "substituable chores" is an essential element of the computation of an enlarged GDP. The results show that incorporating the value of domestic production changes a lot the total resources of the household, both in level and as concerns their dispersion among the population. The evolutions of households monetary income and enlarged income including the value of their domestic production also differ largely, specially in the short term, as proved by an analysis of the results on a four years polish panel.

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Appendix : Datasets

I. Matching Procedure

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 Hammermesh 2006 for a discussion). The commodity consumption structure does not correspond exactly to what is very 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 (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 commodity production. For France, like for Israel and United States in Gronau-Hamermesh paper, the goods/time intensity is relatively high for Dwelling, Health, Clothing and to the less extent for Transport. However, the Eating item differs considerably between France and these countries, being weakly good intensive in France (0.57) and highly good intensive in the US and Israel (1.62, 1.82 respectively).

The matching procedure of a Family Expenditures survey with a Time-Use survey is either made by a regression of the time-uses observed in the matched survey using common covariates observed both surveys (such as education level and the age of the head, the family demographic structure or location), or using the Rubin's Multiple Imputation method (1986) which takes into account the correlations (conditional to covariates) for each variable which is matched between the two surveys (see Alpman, 2017, and Alpman, Gardes and Thiombiano, 2015[7]). A matching of the Consumer Expenditure and the American Time use surveys using both methods shows that simple matching by regression gives often similar estimates. On the other hand, Alpman (2017) compares regression based imputation with Rubin's multiple imputation for simulated data and shows that the later furnishes imputed data which are closer to the original dataset. In Alpman and Gardes (2017), we use a survey containing both monetary expenditures and

[7]Rubin's procedure does not assume implicitly that the variables to be matched are conditionally independent, which is implicitly supposed by other statistical matching methods. This assumption leads to highly biased results when it is not verified by the dataset (see Rubin, 1986 and the Stata program in Alpman, 2017).

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.

II. Countries

Burkina Faso

Burkina Faso is located in West Africa. The country accounts for 16.9 millions of citizens having an average life expectancy of 56 years. The population is very young (46% of young less than 15 years). The country is ranked 181th over 187 countries based on its human development (United Nations Development Program, 2014). The per capita GDP is 720 US dollars, mainly concentrated in the service sector (52%), industry and agriculture representing only 26% and 22%. Its average annual economic growth has been 5% since 2000, the unemployment rate is 3%, but 83% of the population is below the poverty line according to the UNDP multidimensional index and 40.1% according to the National Institute for Statistics and Demography (INSD, 2015), with 92% of the poor in rural areas. The data used for this study are taken from the 2008 round of the farm household survey conducted by the Ministry of Agriculture of Burkina Faso. The survey covers 71 villages in the 45 provinces, with a total of 6941 households surveyed. It contains information on family characteristics (incomes from agriculture or other activities, age of the head and the spouses, number and age of children, education level, accessibility to social services, income, financial situation, equipment...), households' expenditures (over 40 goods and services) and time use over 14 activities: unproductive activity, rain fed agriculture, vegetable farming, arboriculture, livestock farming, fishing, gathering, wood harvesting for selling on a market, wood harvesting for household needs, search for water, market work, other domestic activities, personal activities, other activities. Times are recorded for all adults in the family, while expenditures concern the whole family, including children (the numbers of adults and children are on average 5.36 and 5.72 respectively). The hypothesis is thus made that only adults contribute to the domestic productions. Time uses for activities such as gardening or cattle breeding are both for domestic use and for selling products or services on the market. We have no information on this repartition so that we made the assumption that 70% of time uses corresponds to consumption by the household and 30% to a production

which is sold on the market. In this paper, the monetary expenditures and the time use have been grouped into three common domestic activities: (i) food (ii) domestic activities and (iii) leisure and other activities. Expenditures are recorded for one week for food and one quarter for other expenditures, while time uses correspond to one week. All have been transformed into yearly values. As family size can be very large, time uses corresponding to all adults in the household may be performed in fact by a small part of these households (say two or three). The descriptive analysis in Gardes and Thiombinao (2017, Table 1) indicates indeed that couples with two adults have a significantly greater ratio of monetary expenditures to time uses than singles, which shows that their time are not the fact of all adults in the family. In order to correct for this probable bias, time uses have been multiplied by the ratio of the OECD equivalence scale (one for the first adult, 0.7 for other adults) over the number of adults (which perhaps still overstates the true number of adults corresponding to recorded time uses).

Canada

The Survey of Household Spending for 1998 is matched with the survey of time use budgets contained in the General Social survey for the same year. The family size and the number of children are not informed sufficiently so that the matched sampling contains only couples with zero or one child less of 14. The categorization of time use in the SHS is very similar to the categorization of spending in the SHS simplifying our task considerably. The matching is made using the Rubin's method.

France

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, edu-

cation 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 for the corresponding units in the FES survey.

Poland

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). The matching procedure is made by regression 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 Family Expenditure survey. We define 6 types of activities or time use types compatible with the available data both from FES and BDT: food, housing, clothing, transport, leisure and various expenditures (including health services).

USA

The Consumer Expenditure (CE) survey is performed each quarter over 5000 to 7000 households. Usual expenditures are recorded on a weekly basis, some less frequent for one month. It is matched to the American Time Use survey (ATUS) which gives detailed information on time budgets for one year (see a presentation of these data in Aguiar et al., 2013). Both surveys are delivered each year since 2003. A continuous matching has been made between 2003 and 2011 (see Alpman and Gardes, 2015) using the Rubin's method.