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Welfare Comparisons, Economies of Scale and Equivalence Scale in Time Use

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How do within-couples' time use interactions generate welfare in the family? In this paper we model economies of scale in time use. Following BROWNING, CHIAPPORI, and LEWBEL [2013], we allow intra-household bargaining power to affect the distribution of welfare gains in the family. We estimate the model by means of the UK Time Use Survey (2000). Results suggest that two singles living apart need about 2h15 more spare time a day to achieve the same utility level as when living in a couple. A single woman requires on average 55% of a couple's time resources to be as well-o as when she lived in a couple. The time-poverty threshold is on average 15 hours per individual each day.*

I. Introduction

Equivalence scales are widely used to make interpersonal welfare comparisons of households of different sizes, compositions and characteristics. These scales allow converting observed expenditures of different types of households in to comparable units (LECHENE [1993], BANKS, BLUNDELL, and LEWBEL [1997]). They result from economies of scale, which are cost advantages for couples as compared to two singles living apart. For example, sharing the accommodation, heating and so forth generates economies of scale and welfare gains that can be measured using equivalence scales. These gains vary depending on household composition and income. These scales are widely applied to define poverty lines. Traditionally, welfare level is exclusively defined on a good consumption basis (NELSON [1993]). However, the allocation of time can be viewed as "*the ultimate source of utility*" (ZECKHAUSER [1973]), since the marginal utility of leisure is positive, and the utility of good consumption can be valued only if an individual has time. Sociologists argue that life satisfaction has temporal aspects as 'spare time' affects individual's subjective well-being (ERIKSSON, RICE, and GOODIN [2007]). Time-poverty is a concept that is of growing interest in the literature (VICKERY [1977], GOODIN *et al.* [2005], HAMERMESH and LEE [2007]).

In this paper, we estimate a household's time allocation model that allows identification of economies of scale in the time allocation process of a family. We define equivalence scales based on time use. This paper brings a better understanding of how family interaction converts time into welfare. It allows the following question to be answered: "How much time does a

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couple save by living together versus living apart?" "How much time would a single female require to attain the same utility that she would have if she lived in a couple?" Indeed, living in a couple means saving time, because, for example, cooking for two does not require twice as much time as cooking for one. Thus, living together and sharing creates economies of scale within the household. It implies that a widow needs more spare time to achieve the same welfare that she had living in a couple. To our knowledge, excepting VAN HOA and IRONMONGER [1989], there has been no attempt in the economic literature to identify such economies.

In the poverty analysis undertaken here, individual time is taken as the only source of utility. While daily time endowments are identical across individuals, their freedom to allocate time to non-market activities differs. As emphasized by BITTMAN [2011] and GOODIN *et al.* [2008], an individual who declares that he has "more time than someone else" does indeed refer to his autonomous control of his time. This ability to choose is related to Sen's capability concept (SEN [1985]) and has a crucial impact on well-being. We consider that, from a daily perspective, the time spent on the labor market is the most constrained, whereas the other types of time-use categories (housework, sleeping or leisure) could be allocated freely.

Working time is used to achieve a material standard of living that is somehow ruled out from the analysis. It is obvious that time poverty does not systematically go in the same direction as money poverty. To this respect, the analysis is partial since no money compensation can be considered in this framework to correct for time inequalities, and time is not transferable. This limits the policy perspectives of our analysis. However, this model is a stepping stone towards achieving this aim.

We model the process by which individuals' uses of time are transformed into welfare, taking into account interaction in the family. Unlike single individuals, people who live in a couple have imperfect control of their spare time because the use of time is negotiated with the partner. The balance of power in the couple determines who is more in line with his/her wishes in the family. Having more control over one own's use of time is then interpreted as being richer in terms of time. Time could also be gained since it is possible to "save time" through the production of an implicit household public commodity that every household member enjoys (e.g.: a clean house). Time externalities can also occur, since it is possible to gain welfare – and thus time – if one enjoys seeing one's partner undertaking some kind of time-use activity, like playing tennis. Hence, by disentangling time-use categories – especially leisure activities – from household chores, we allow different types of time to impact on different types of individuals in different contexts of household composition.

From a methodological point of view, this paper follows the literature that treats theoretical controversies regarding the definition of equivalence scales. Traditional equivalence scales define an *equivalent income* at the household level, answering the following question: "what is the expenditure level required by a single household to be as well off as if it was a household with several members?". To achieve this aim, utility cardinalization is required, which has been widely criticized (see POLLAK and WALES [1979; 1995], GRONAU [1988], NELSON [1988], BROWNING, CHIAPPORI, and LEWBEL [2013] for more details). Additionally, the traditional definition assumes that – within households – welfare levels are equalized (NELSON [1993]). Recently, BROWNING, CHIAPPORI, and LEWBEL [2013] stated that in the standard approach *"the notion of a household utility is flawed. Individuals have utility, not households.*

What is relevant is not the 'preferences' of a given household, but rather the preferences of the individuals that compose it." They proposed a new definition of an equivalence scale that maintains ordinality of utilities, and thus free from the drawback noted above. BROWNING, CHIAPPORI, and LEWBEL [2013] estimate *adult-indifference scales.* To achieve this aim they define *individual equivalent incomes*[1] so as to answer the following question: "what is the expenditure level required by a single individual to be as well off as if he was member of a household with several members?". In this case, instead of comparing cost functions of households of different types, an unique individual cost function in two different marital situations is compared, making it possible to analyze the possible intra-household variation in standard of living.

The BROWNING, CHIAPPORI, and LEWBEL [2013] analysis is based on a collective representation of the household decision-making process. The household is the scene of a bargaining process among its members, where the *sharing rule* characterizes the bargaining power of each member (BROWNING, CHIAPPORI, and LEWBEL [2013], APPS and REES [1988], BROWNING and CHIAPPORI [1998], VERMEULEN [2002], CHIAPPORI and DONNI [2006], FORTIN and LACROIX [1997]). In this case, the household utility function is defined as a weighted sum of family members' individual sub-utility functions. Household behavior is taken to be Pareto-efficient. To capture economies of scale in consumption, BROWNING, CHIAPPORI, and LEWBEL [2013] introduce a *consumption technology function* that characterizes the intra-household publicness of the consumption of goods or, alternatively, describes positive externalities associated with the consumption of goods within the household. CHERCHYE, DE ROCK, and VERMEULEN [2012] use the BROWNING, CHIAPPORI, and LEWBEL [2013] framework to analyze economic well-being and poverty among the elderly.

VERMEULEN and WATTEYNE [2006] and LEWBEL and PENDAKUR [2008] provide an alternative specification that eases identification. VERMEULEN and WATTEYNE [2006] propose giving up the consumption technology function. They *a priori* define goods that are privately consumed and those which are publicly consumed. LEWBEL and PENDAKUR [2008] and BARGAIN and DONNI [2012] provide a model relying on Engel curve estimates, without price variation. Within this framework, BARGAIN and DONNI [2012] provide a new concept of child cost.

Our model brings new elements to the BROWNING, CHIAPPORI, and LEWBEL [2013] framework. We introduce a time-use technology function that reflects intra-household economies of scales over time. The links between good and time consumption are clarified thanks to a time separability assumption tested in the empirical part of this paper. Our contribution brings a first stone in the building of a complete model of intra-household welfare interaction through consumption and leisure. We apply the model to UK time-use data. The results show that two singles living apart need 2 hours and 15 minuts more spare time a day to achieve the same utility level as when living as a couple. A single woman requires 54% of joint-time resources to attain the same utility level that she would have if living in a couple, and men 52%. Time-poverty lines are also defined. 3% of our sample is considered as time-poor, that is as having less than 15 hours spare time a day.

1. Note that the notion of individually-based equivalence scales is present earlier in the sociological literature (BITTMAN and GOODIN [2000]).

This paper proceeds as follows. SECTION II presents the theoretical model; SECTION III then presents the identification strategy and SECTION IV the empirical framework and results. SECTION V concludes.

II. Households' Daily Time-Allocation Choice

We present the model under a separability assumption which requires that hours of work and consumption do not impact on daily time allocation, except through an income effect. In this model, the time-use allocation decision is conducted on a short-term daily basis, i.e. the allocation of spare time amongst non-market activities. Medium-term choices, such as consumption or hours of work are taken as given.

Each day, individuals have a time endowment of 1440 minutes, denoted T. Although this time endowment is the same for everybody, the amount of time that individuals can control varies in the population and generates what we denote as "time inequalities". Spare time, $\widetilde{T}$, is defined as total time T minus time spent working on the labor market, denoted H. On a daily perspective, working time is presumably the most constrained activity. Individuals can then freely choose to allocate their spare time among various uses: housework, sleeping, personal care, commuting, and 'pure' leisure. From a behavioral perspective, the predetermination of consumption and hours of work makes sense. Indeed, usually a worker receives his wage and salary monthly. The labor contract defining wages and working hours is often contracted for a longer time period. Working hours can evolve over shorter time periods, but this is mostly explained by the employers wanting to ensure higher flexibility of the production process.

Household members, identified by subscript $i = f, m$, are endowed with a well-behaved utility function depending on a vector of K commodities (denoted $\mathbf{z}$): $U_i(\mathbf{z}_i)$. These commodities, $\mathbf{z}$, are generated by a production process that uses time spent at various activities as inputs. Individuals and households are heterogeneous in their capabilities of transforming time-uses into welfare: their perception, needs and abilities to produce welfare is heterogeneous.

II.1. *The Time-Use Technology Function*

The time-use technology function describes how time inputs are transformed into private time equivalents that enter the welfare functions of household members. It has two implications. First, it allows us to introduce heterogeneity into the abilities to transform time-use into welfare. Second, it allows us to understand how couple life generates welfare gains in time-use. This concept is inspired by a BECKER [1965]-type household production model and by the consumption technology function (see BROWNING, CHIAPPORI, and LEWBEL [2013] and CHERCHYE, DE ROCK, and VERMEULEN [2012]).

Let $\mathbf{z}_i = (z_i^1, z_i^2, \ldots, z_i^K)$ be a vector of private time equivalents, while $\mathbf{t}_i = (t_i^1, t_i^2, \ldots, t_i^K)$ is a vector of time effectively spent. The time-use technology function takes the form of a linear Barten-type technology: the vector of private equivalents $\mathbf{z_i}$ is assumed to be linearly produced within the household using its members' uses of time: $\mathbf{z} = \mathbf{z}_f + \mathbf{z}_m = F(\mathbf{t}_f, \mathbf{t}_m)$, the F function having the following property: for $k \neq k'$, $\frac{\partial^2 F_i}{\partial t_i^k \partial t_i^{k'}} = 0$.

In single households, there are no economies of scale, the different time-use activities are directly considered to be commodities entering into the individual utility function: $\mathbf{z}_i = \mathbf{t}_i$.

The interpretation of the relationship, F, is twofold. On the one hand, it can simply be viewed as a household production process with constant returns to scale and perfect substitutability of time-use activities. In this view, commodities produced by the household are assignable to household members. The process describes how an aggregate private good commodity vector $\mathbf{z} = \mathbf{z}_f + \mathbf{z}_m$ is produced at the household level and then shared amongst household members. Production of a dinner could easily enter into this category.

On the other hand, the set up can be regarded as a time-use generalization of the consumption technology function. The consumption technology function proposed by BROWNING, CHIAPPORI, and LEWBEL [2013] transforms household effective purchases into private good equivalent bundles. The *time-use technology function* transforms time effectively spent $\mathbf{t}_i$ into private time equivalent $\mathbf{z}_i$. It allows one to define equivalence scales on an individual basis (denoted *adult indifference scales*). It also describes how time-use externalities induced by family status (being single or in a couple) impacts on individual welfare. This interpretation could correspond to leisure activities, like playing tennis together, for example. As noted by BROWNING, CHIAPPORI, and LEWBEL [2013], unlike Becker's domestic production function, the technology function implies an additional restriction. Here, the set of inputs is identical to the set of outputs: couples produce the equivalent of a greater quantity of time via sharing and togetherness of non-market activities.

Overall, the F function summarizes how welfare in time is generated by the couple. It mixes perception, consumption and production effects. The economies of scale generated by the use of time in the k^{th} activity increases individual welfare, first, because it contributes to the production of an intra-household public good that every household member can enjoy (a clean house). Second, there is a direct welfare externality (one feels happy when playing tennis with one's partner).[2]

The specification of F can be simply written in the following way:

$$\begin{cases} z_f^k = t_f^k + \alpha^k t_m^k \\ z_m^k = t_m^k + \alpha^k t_f^k \end{cases} \text{, for } k = 1, ..., K \tag{1}$$

α^k is the degree of publicness of the time. Each non-market activity has a private and a public component. Hence $0 < \alpha^k < 1$, where 0 refers to purely private time and 1 to purely public time.[3] The lower α^k, the more private the k^{th} non-market activity. The private equivalent of a woman living in a couple, z_f^k, is composed by the time spent by this woman in activity k, t_f^k plus the public part of the time spent by her partner m on this same activity k, $(\alpha^k * t_m^k)$.

2. To ease interpretation and estimation, the specification does not allow any externalities among different time-use activities. This means that individuals cannot "save" time in the k^{th} activity by spending time (or if the partner spends time) in the $k^{'th}$ activity. In other words, it is not possible to increase one's cooking productivity by spending more time playing tennis.

3. To be invertible, F has elements $\alpha^k \neq 1$ in order to $1-(\alpha^k)^2 \neq 0$. For identification purpose the cases of purely private and purely public time-use activity are ruled-out.

II.2. *Time-Use Demand for Singles*

We first describe the behavior of single households. For the sake of simplicity the household's subscript is omitted. According to our separability assumption, the medium-run choices only impact on the time-use allocation through a time endowment effect. On a daily basis, each rational agent maximizes a well-behaved short-run utility function, denoted U, with respect to a daily time-use allocation, subject to a time constraint. We denote $\mathbf{t} = (t^1, ..., t^K)$ the individual time-use vector and $\widetilde{T}$ the spare time endowment:

$$\max_{\mathbf{t}_i} U_i(\mathbf{t}_i) \begin{cases} \text{st. } \Sigma_{k=1}^K t_i^k = \widetilde{T}_i \\ \text{st. } t_i^k \geq 0, t_i^k \leq T \end{cases} \tag{Ps}$$

Daily time-use demands can be written in the following way:

$$t_i^k = t_i^k(\widetilde{T}_i) \text{ for } k = 1, ..., K. \tag{2}$$

Daily time-use demands are identical to the commodity demand since $\mathbf{t}_i = \mathbf{z}_i$. In the single individual case, prices of different activities are the same. This hinders identification of price elasticities. However, since wage rates, as well as short-run spare time $\widetilde{T}$ vary across individuals, it is possible to identify these elasticities under certain parametric restrictions described later in the text.

II.3. *Commodities and Time-Use Demand for Couples*

A couple's daily allocation of time is assumed to be described by a collective model (Apps and Rees [1988], Browning *et al.* [1994]). Time allocation in the short run (i.e. on a daily basis) will be efficient and taken to be conditional on medium-run consumption and labor-supply choices. For the couple, the individual time constraints are $\Sigma_{k=1}^K t_f^k = \widetilde{T}_f$ and $\Sigma_{k=1}^K t_m^k = \widetilde{T}_m$. Therefore, the household daily time-allocation program (P^c) for the case of couples is:

$$\max_{\mathbf{z}_f, \mathbf{z}_m, \mathbf{t}_f, \mathbf{t}_m} \mu(.).U_f(\mathbf{z}_f) + U_m(\mathbf{z}_m) \begin{cases} \text{st. } \Sigma_{k=1}^K t_i^k = \widetilde{T}_i \\ \text{st. } \begin{array}{l} z_f^k = t_f^k + \alpha^k t_m^k \\ z_m^k = t_m^k + \alpha^k t_f^k \end{array} \\ \text{st. } t_i^k \geq 0, t_i^k \leq T \text{ for } i = f, m \text{ and } k = 1, ...K \end{cases} \tag{Pc}$$

The Pareto weight μ generally depends on prices, incomes and possibly distribution factors.[4] It reflects the weight of individual sub-utility in the household decision-making process.

We now focus on interior solutions.[5] To achieve this aim, broad definitions of non-market activities will be chosen in order to make sure that all household members spend a positive amount of their time on each of these categories.

4. A distribution factor is a variable that affects bargaining power but not preferences of individual household members or the setting of the joint budget.

5. Extending the empirical approach to corner solutions would make it possible to consider a greater number of time-use activities. However, this extension to the structural daily time-use allocation case is not straightforward. In structural collective models, considering non-participation to labor-supply choices is now relatively standard (Donni [2009], Bloemen [2010]), but this is not the case when considering several uses of time. Furthermore, in the case of daily time-use, additional identification assumptions would be necessary to disentangle infrequent answers from actual non-participation choice in some daily activities (Browning and Bonke [2006]). Given the novelty of the approach undertaken here, we postpone this problem to further research.

Solutions of program (P_c) can be rewritten as the solution to the individual decentralized program (P_d):

$$\begin{cases} \max_{\mathbf{z}_i}\ U_i(\mathbf{z}_i) \\ \text{st.}\Sigma_{k=1}^{K}\pi_i^k z_i^k = \eta_i \end{cases} \tag{Pd}$$

In the decentralized case, the sharing rule η is the share of income an individual living in a couple can spend on private commodities. The cost of private commodities is evaluated at a shadow price (LINDAHL [1919]), denoted π, that itself depends on how economies of scales in time are generated in the household. Pareto weights and the sharing rule both refer to the bargaining power in the decision process: the higher the weight μ and the sharing rule η_f, the greater the private time equivalent consumed by the female individual z_f^k. In principle, estimating the decentralized program is preferred since the sharing rule does not depend upon any cardinalizations of the utility functions U_f and U_m, unlike the Pareto weight μ.

Because of the separability assumption between the medium and short run, the Pareto weight and the associated sharing rule in the conditional program only depend on distribution factors and income effects (available time, which is the equivalent to second-step income in a two-step budgeting procedure). If separability does not hold, then efficiency at the second level cannot be guaranteed (BLUNDELL, CHIAPPORI, and MEGHIR [2005]). As a consequence, prices related to medium-run choices (wage rates) impact on decisions in the short run. In this case, the sharing rule and the Pareto weight would depend on the wage rate.

Each time-use activity has an implicit shadow value (see Appendix A):

$$\begin{cases} \pi_f^k = \frac{\lambda_f T_m - \lambda_m T_f \alpha^k}{\lambda_f T_f T_m\left[1-\left(\alpha^k\right)^2\right]}\eta_f \\ \pi_m^k = \frac{\lambda_m T_f - \lambda_f T_m \alpha^k}{\lambda_m T_f T_m\left[1-\left(\alpha^k\right)^2\right]}\eta_m \end{cases} \tag{3}$$

where λ_i is the Lagrangian multiplier associated with the individual time-constraint which represents the opportunity cost of domestic time for the household member i.

Unlike BROWNING, CHIAPPORI, and LEWBEL [2013], in our case individual shadow prices do vary within the household, meaning that individuals have different marginal valuations for the activities. It is worth indicating that the individual perceptions (implicit cost) of time-uses varies because of the time saving technology (α^k). The higher the degree of publicness, the lower its shadow price. Economies of scale and inequalities in spare time affect differently the shadow price of each time category and individual.

Conditional demands for commodities $\mathbf{z}_i$ are obtained for program (P_c) or (P_d) :

$$z_i^k = h_i^k(\pi_i^1,...,\pi_i^K,\eta_i) \tag{4}$$

It is worth indicating that private equivalents $\mathbf{z}$, shadow prices π and the sharing rule η are not observed, while time-uses are. Hence, it is relevant to derive the shape of time-use demands. Inverting equation (1) and substituting the $\mathbf{z}$ by the above demand leads to structural time-use demands:

$$\begin{cases} t_f^k = \frac{1}{1-(\alpha^k)^2}h_f^k(\pi_f,\eta_f) - \frac{\alpha^k}{1-(\alpha^k)^2}h_m^k(\pi_m,\eta_f) \\ t_m^k = \frac{1}{1-(\alpha^k)^2}h_m^k(\pi_m,\eta_m) - \frac{\alpha^k}{1-(\alpha^k)^2}h_f^k(\pi_f,\eta_m) \end{cases} \tag{5}$$

II.4. *Economies of Scale and Indifference Scales*

Economies of scale measure the extra time that two singles living apart need to have to be as well off as when living together. The gains associated with household jointness of time-use can be unequally shared within the family. Economies of scale in time-use represent the cost in time needed to consume the private time equivalents ($\sum_{k=1}^{n}(z_f^k + z_m^k)$) in comparison to what the household spends ($\tilde{T}$).

Following BROWNING, CHIAPPORI, and LEWBEL [2013], we define the relative economies of scale in time-use, e, by:

$$e = \frac{\mathbf{p}'[\sum_{k=1}^{n}(z_f^k + z_m^k) - \tilde{T}]}{\mathbf{p}'\tilde{T}} = \frac{\sum_{k=1}^{n}(z_f^k + z_m^k)}{\tilde{T}} - 1 \tag{6}$$

where $\mathbf{p}$ is a vector of one and $\widetilde{T} = \widetilde{T_f} + \widetilde{T_m}$, the household total spare time.

The indifference scales IS_i represent the fraction of household time resources that a single i would require in order to consume the time private equivalents $\mathbf{z}_i$ at market prices. In this case, it makes it possible to achieve exactly the same level of utility with the same indifference curve when living in a couple and when living alone:

$$IS_i = \frac{Min_{\mathbf{z}_i^*}(\mathbf{p}'\mathbf{z}_i^* | u_i(\mathbf{z}_i^*) = u_i(\mathbf{z}_i))}{\mathbf{p}'\tilde{T}} \tag{7}$$

In expression (7), the numerator corresponds to the minimal time-expenditures spent by a single individual to achieve the same welfare level as living in a couple; and the denominator corresponds to couple time-expenditure.

Indifference scale involves the definition of the equivalent time resources, T_i^*, describing the minimum amount of spare time required to consume the vector of private time equivalent $\mathbf{z}_i$, which makes it possible to attain the same welfare as in a couple: $T_i^* = \sum_{k=1}^{n}(\mathbf{z}_i^k)$. In this case, the individual indifference scale is the ratio $IS_i = \frac{T_i^*}{\tilde{T}}$. A single individual would require a proportion IS of the total time resources to be as well off as when living in a couple.

III. Identification Strategy

The reduced-form time-use demands of a couple only depend on observables $\widetilde{T_i}$ and the observed heterogeneity variables $\mathbf{x}$:

$$\begin{cases} t_f^k = t_f^k\left(\widetilde{T}_f, \widetilde{T}_m, \mathbf{x}\right) \\ t_m^k = t_m^k\left(\widetilde{T}_f, \widetilde{T}_m, \mathbf{x}\right) \end{cases} \tag{8}$$

Structural time-use demands are defined above in equation (5). They depend on the commodity demands of both members of the couple, h_f and h_m, and on the parameters of the time use technology function, α^k. Commodity demands themselves depend on the shadow prices π_f and π_m that were derived in the preceding section. These prices are themselves a known function of observables as well as of the parameters of interest α and Lagrangian multipliers λ_f, λ_m which represent the opportunity cost of domestic time.

The identification question is the following: "Can we identify the parameters of the time-use structural technology function, the preference parameters, and the intra-household sharing rule (equation 5) from the observation of a time-use demand for singles and couples (equations 8 and 2)?" To achieve this aim, certain conditions must be satisfied. First, following the literature, we assume that conditional individual preferences for time are the same whatever the marital status. Second, time-use preferences, and especially price elasticities, should be identified from the estimates obtained for singles. Third, the individual share of a commodity is assumed to be proportional to his or her contribution to the household time-resources.

Assumption 1. Conditional on observed heterogeneity, commodity demands h_f and h_m are the same, whatever the marital status.

This assumption, despite being controversial, is common in the literature (COUPRIE [2007], BARGAIN and DONNI [2012], LEWBEL and PENDAKUR [2008], LISE and SEITZ [2011]). When thinking about reasons why this assumption might not hold (e.g. preferences for time might differ depending on family status), two main considerations come to mind: heterogeneity and welfare interactions. Both of these reasons are controlled for in the current model, so Assumption 1 is not as strong as it might appear at first sight. Firstly, in the empirical specification, preference heterogeneity is included, so this assumption of preference equality is applied conditional on observed characteristics. Secondly, welfare interactions due to time-use in the family need to be adequately controlled for. The time-use technology function accomplishes this. Our view is that it is the case that this function adequately summarizes these interactions. However, we do recognize that this assumption could be problematical if the marriage or divorce processes are themselves related to time-use preferences or time-use interaction in the family, a situation that cannot be formally excluded.

Assumption 2. Preferences are strongly separable and additive, and income effects vary across activities.

Structural estimation of the time-use demand function for couples can only be complete if the identification of time-use demand is achieved for singles. This is, however, problematical since prices remain fixed for singles. Consequently, the price elasticities of each activity cannot be individually identified. Indeed, if we denote by h the structural time-use demand for singles and by ζ the reduced-form one, we have that :

$$t^k = h^k(p^1,...,p^K,\widetilde{FI}) = \zeta^k(w,\widetilde{FI})$$

where $\widetilde{FI}$ is the full income minus consumption and $p^1 = ... = p^K = w$. In this case, price effects cannot be separately identified ,since ζ is observed whereas h is not:

$$\frac{\partial \zeta_k}{\partial w} = \Sigma_{j=1}^{K} \frac{\partial h_k}{\partial p_j}$$

Assumption 2 leads to a direct utility function $U(.)$ which is made up of sub-utility functions for each commodity group (t^k) combined additively, up to any monotonic transformation F: $U = F(u^1(t^1) + u^2(t^2) + ... + u^K(t^K))$. The strong separability assumption for additive preferences allows us to identify all price effects using only one price variation and wealth effects.[6] It is a necessary assumption to identify price effects in the case of time-use since prices are the same across various activities. With it, all price effects are identified. Indeed, cross-price substitution effects among time-uses are a function of income effects – up to a multiplicative constant.

A Stone-Geary utility function presents the interesting property that price derivatives can be identified using only variations on wage and full income data. This certainly eases identification in our context since we do not have any price variation of time-use activities. The only variation is in income.

Assumption 3. A household member commodity share is proportional to his or her household daily time-budget contribution.

As is obvious from equation (LINDAHL [1919]), the sharing rule cannot be separately identified from the Lindhal prices. We specify a sharing rule that corresponds to the individual conditional full income: $\eta_i = \widetilde{FI}_i$. This assumption makes sense. An individual who enjoys more spare time and/or who has a higher wage rate in the household consequently has greater bargaining power and would be able to extract a higher share of household resources regarding time-use. In other words the individual who works less and/or who has the higher wage rates will have more control (and thus happiness) over her/his uses of time because the household decision is taken more in line with her/his wishes. This usually corresponds to a focal point in household consumption arrangements (individual expenditures proportional to individual contribution to household income). This kind of assumption has already been used in structural estimations of household models (APPS and REES [2001]).

Following BROWNING, CHIAPPORI, and LEWBEL [2013] and CHIAPPORI and EKELAND [2006], we obtain a generic identification of the model. For $K \geq 1$, generic identification of the time-use technology parameters of α^k and the individual opportunity costs λ_f, λ_m is achieved. It is straightforward to show that we have more equations than unknowns. Can we identify the $K-1$ parameters of the time-use technology function and the *two* individual opportunity costs λ_f, λ_m from the observation of the reduced-form time-use functions (equation (8))? Note that, we have $K+1$ unknowns and $2K$ independent equations. If $K \geq 1$, then $2K \geq K+1$ and the number of equations exceeds the number of unknowns. Given identification of the $K-1$ parameters α and the *two* individual opportunity costs λ_f, λ_m.; and given the sharing rule defined in Assumption 3, this allows us to recover the Lindhal prices for all the activities: π_f^k and π_m^k, $k = 1, ...K$. Private equivalents can be recovered from equation (1).

IV. Empirical Application

IV.1. *Data*

We use the UK Time-use Survey 2000[7] which measures the amount of time spent on various activities. Respondents are asked to complete two 24-hour dairies (for a working and a non-working day), broken down into ten-minutes slots. We use the weighted mean of the two diaries.

6. See DEATON and MUELLBAUER [1980], p. 137.
7. Ipsos-RSL and Office for National Statistics, United Kingdom Time-use Survey, 2000. 3rd Edition. Colchester, Essex: UK Data Archive, September 2003. SN: 4504.

Hence, each number of minutes presented here is the average daily time devoted to one activity. The questionnaire includes socio-demographic details and variables on employment and income.

TABLE I. – Descriptive Statistics

Variable	Single female	Single male	Female in couple	Male in couple
Wage	7.07 (10.65)	6.19 (3.90)	5.02 (3.27)	6.90 (9.74)
Age	40.27 (11.12)	39.31 (10.93)	41.20 (12.35)	43.25 (12.45)
Education	3.77 (1.84)	3.61 (1.98)	3.36 (1.87)	3.41 (1.93)
House ownership	0.75 (0.44)	0.64 (0.48)	0.84 (0.36)	0.84 (0.36)
Car ownership	0.73 (0.45)	0.68 (0.47)	0.93 (0.26)	0.93 (0.26)
Available Time[a]	1,098.77 (123.60)	1,054.57 (148.32)	1,117.31 (128.09)	1,060.26 (135.10)
Hours worked[a]	320.49 (117.97)	371.72 (138.84)	309.44 (127.05)	368.99 (134.59)
Sleep[a]	493.83 (73.73)	472.71 (88.81)	496.71 (68.41)	479.79 (75.61)
Personal care[a]	124.47 (47.79)	109.55 (52.41)	126.66 (48.82)	117.00 (53.39)
Household work[a]	144.87 (87.06)	96.44 (78.58)	173.42 (98.63)	111.72 (82.59)
Pur leisure[a]	252.74 (95.10)	277.29 (122.34)	231.70 (89.17)	264.16 (106.57)
Commuting[a]	82.87 (42.47)	96.46 (60.84)	87.73 (51.71)	86.51 (52.22)
Observation	159	194	379	379

[a] In minutes per day. Standard deviation in parentheses.

We focus on working couples or single individuals without children.[8] Our sample contains 1,111 workers between 16 and 65 years old of age. We take a sample of single females (159), single males (194) and couples (379) with no-one else present in the household. TABLE I presents descriptive statistics. The hourly wage rate is computed as the quotient of weekly labor earnings by weekly working hours. Following BROWNING and GØRTZ [2006], the wage rate was not derived by dividing the labor income by the number of worked hours according to the time-use module, but rather from the income module. While single women earn on average more than single men, it is the opposite for those living in a couple. Following the labor economics literature, we use six dummy variables measuring the education level from no qualification to doctorate level, distinguishing primary school from secondary, tertiary and professional. Single women are also older and better educated than women living in a couple, whereas cohabiting or married women are less educated and younger than their male counterpart. Our sample includes a high share of homeowners and car-owners.

The spare time is derived by subtracting declared working hours, including work-related training, according to the time-use module over 24 hours. It is then allocated between non-market activities. We used the following non-market activity categories : sleeping, personal care and self-maintenance, housework (that is household maintenance, management, shopping for

8. The inclusion of children raises additional identification issues. Are children decision-makers ? How does the welfare of children interact with their parents? How does the productive behavior of children interact in the household production process ?

the household and care); leisure (social and cultural activities and mass media use), and lastly commuting i.e. time spent going to work.

The descriptive statistics suggest that women are "richer" than men in terms of spare time. This could be due to some UK-specific characteristics in the labor market. As noted by BLUNDELL *et al.* [2007] men's labor supply is a discrete choice between working full time or not working, while women's labor supply displays a wide range of hours of work, and a large number do not work. Higher flexibility in the female labor contract implies higher heterogeneity within female as opposed to male spare time. Moreover, it also implies higher average female than male spare time.

Concerning individual diaries, consistent with the previous findings, women devote more time to sleeping and personal care on average than men. They also perform more housework and have less leisure, especially for women in couples. Interestingly, women work less on average than men, whatever the marital status, and singles work more than individuals living in a couple.

A frequent problem in time-use analysis is the zeros reported for some activities. They could reflect infrequency case or preferences. The first case is a statistical artefact, whereas the second is a "corner solution". BROWNING and BONKE [2006] propose a method to correct for infrequency bias, assuming that some zeros are linked to preferences and others to infrequency. However, concerning time-use, it is difficult to make this kind of assumption.

By using aggregated definitions of uses of time and taking the average time devoted to each activity between the two individual diaries (working day and non-working day), we can significantly reduce the frequency of zeros. Focusing on both working and non-working days is critical for our analysis, since housework and leisure activities are mainly done on a non-working day. Indeed, some activities, like sport or house cleaning, are performed once a week. Second, using aggregate categories – like housework – leads to a reduction in the frequency of zeros: less than 1% of our observations.[9] This could be explained by the lower frequency of some tasks: for example, gardening is seasonal and sometimes performed monthly. Moreover, the specialization of domestic chores occurs, defining female-oriented tasks as cooking, and male tasks. Yet, this is not our focus. Even if specialization could explain the gain resulting from marriage (BECKER [1965]) and economies of scale, this paper aims to estimate economies of scale resulting from the publicness of the activities.

Aggregate activities are chosen in the following way. First, we are interested in time gains as the main economic reason for forming a couple (that is domestic production and housework). Then, we define leisure as the main source of utility according to the standard economic literature. This is consistent with the growing literature on spending leisure together (FONG and ZHANG [2001]). Even if commuting time is highly correlated to working time, it allows some flexibility. Assuming a fixed daily working time does not imply a given working schedule. Finally, we distinguish sleeping and personal care because our identification requires assignable activity (personal care) and adding-up restrictions. Disentangling further time-use activities would be harmful from a practical point of view (more infrequencies). Furthermore, broad categories correspond better to the model specification which assumes the absence of economies of scale externalities across time categories. For example, such an assumption would be more difficult to justify if we disentangled housework time into cleaning the house, dish washing, etc.

9. Considering only a working day generates a higher occurrence of zero:22% of the observations.

IV.2. *Empirical Implementation*

IV.2.1. *Empirical Specification*

Individuals are supposed to allocate the use of their K activities following a Stone-Geary utility function:[10]

$$U(t_i) = \Pi_{j=1}^{K}\left(t_i^j - \gamma_i^j\right)^{\rho_i^j}$$

where t_i^j is the time devoted to the j^{th} activity by individual i. The Stone-Geary parameters, ρ_i^j, are individual and good-specific (marginal budget shares); γ_i^j are the constants.[11] The sum of all good proportions consumed must equal 1 ($\Sigma_{j=0}^{K}\rho_i^j = 1$ and $0 < \rho_i^j < 1$).

The Stone-Geary utility function is a relatively simple specification. However it has three advantages. First, non-linearity is introduced in a simple and parsimonious way thanks to the time-use needs parameter. Second, these needs have an interesting welfare interpretation since individual welfare is allowed to increase as soon as basic needs are achieved, which provides a micro-foundation to what GOODIN *et al.* [2008] call "discretionary time", that is time under control. Last, with this specification, a parametric identification of price elasticities is possible using only variations in income (spare time), even if we do not observe the price of activities for single individuals. These elasticities are necessary later on to identify the implicit individual valuation of commodities for individuals living in a couple.

Adding observed and unobserved heterogeneity, the single demands for time-activity k has the following forms:

$$t_i^k = \gamma_i^k + \rho_i^k(\widetilde{T}_i - \Sigma_{j=1}^{K}\gamma_i^j) + \varepsilon_i^s \text{ , where } i = f, m. \tag{9}$$

We parametrize ρ_i^k in the following way, so including observed heterogeneity ($\mathbf{x}$) in income effects:

$$\rho_i^k = \frac{e^{\mathbf{x}_i\beta_i}}{1+e^{\mathbf{x}_i\beta_i}}$$

Data on single-individuals are used to estimate parameters γ_i^k and ρ_i^k using a classical micro-econometric demand estimation. This is the h function that we can substitute into couple's time-use demand equation (see equation 5). Adding unobserved heterogeneity ε, we obtain:

$$\begin{cases} t_f^k = \frac{1}{1-(\alpha^k)^2}[\gamma_f^k + \frac{\rho_f^k}{\pi_f^k}(\eta_f - \Sigma_{j=1}^{K}\gamma_f^j\pi_f^j) - \alpha^k(\gamma_m^k + \frac{\rho_m^k}{\pi_m^k}(\eta_m - \Sigma_{j=1}^{K}\gamma_m^j\pi_m^j))] + \varepsilon_f^c \\ t_m^k = \frac{1}{1-(\alpha^k)^2}[\gamma_m^k + \frac{\rho_m^k}{\pi_m^k}(\eta_m - \Sigma_{j=1}^{K}\gamma_m^j\pi_m^j) - \alpha^k(\gamma_f^k + \frac{\rho_f^k}{\pi_f^k}(\eta_f - \Sigma_{j=1}^{K}\gamma_f^j\pi_f^j))] + \varepsilon_m^c \end{cases} \tag{10}$$

10. We acknowledge that using a Stone-Geary specification imposes strong restrictions on behaviours. We face similar issues to PROWSE [2009] who estimated couples' time allocation on market and non-market activities: the identification of our model is constrained by the lack of price variation. Indeed, wages are the only observed prices and non-market activities have all the same price. Therefore, there are no cross-price effects for individual's non-market activities in the demand functions we estimated. In such cases, despite its restrictions, the Stone-Geary specification has the advantage allowing a "straightforward and theoretically consistent implementation of the multivariate time allocation model" (PROWSE [2009], p. 95).

11. It is worth indicating that a strict interpretation of the constant in the Stone-Geary specification as the minimum level is misleading here since the γ_i^j's may be negative.

where $\eta_i = \widetilde{FI}_i(\mathbf{x}, s)$ and s includes female to male ratios of wage and education as distribution factors. It is worth noticing that we cannot identify the sharing rule η_i as the time use demands are homogeneous of degree zero. We assume that η_i corresponds to $\widetilde{FI}_i$. Implicitly, this implies that we know the Pareto weight. The following estimation would be conditional to a given Pareto weight μ.

Since we consider that gains from living together and the degree of publicness of time-activity could vary across households, we introduce heterogeneity in α^k, which depends on demographics (female and male age, age squared, qualifications):

$$\alpha_i^k = \frac{e^{\mathbf{x}_i \delta_i}}{1 + e^{\mathbf{x}_i \delta_i}} \tag{11}$$

Equation (3) describes the structural form of the Lindahl prices, which depend on the α parameters and the opportunity cost of non-market time λ_f and λ_m. The latter are the derivatives of the indirect utility function V with respect to spare time, $\widetilde{T}$. The indirect Stone-Geary utility function being:

$$V_i(\mathbf{t}_i) = \Pi_{l=1} K (\rho_i^l (\widetilde{T}_i - \gamma_i^l))^{1-\Sigma_{l \neq j}^{K-1} \rho_i^l}.$$

We derive with respect to spare time $\widetilde{T}$ and obtain:

$$\lambda_i = (1 - \Sigma_{l \neq j}^{K-1} \rho_i^l)(\rho_i^l)\ (1 - \Sigma_{l \neq j}^{K-1})(\widetilde{T}_i - \gamma_i^l))^{-\Sigma_{l \neq j}^{K-1} \rho_i^l}$$

The Lindhal prices can then be recovered. We then proceed to predictions of commodities $\mathbf{z}_i$ implicitly consumed by individuals living in a couple. Summing up these commodities gives a private time equivalent[12] for individuals who live in a couple, denoted $T_i^* = \Sigma_{k=1}^K z_i^k$. Obviously, these amounts depend on the level of economies of scales, for a given Pareto weight. Individual indifference scales and economies of scales can be computed using equations (6) and (7).

IV.2.2. *Estimation Strategy*

The system of time-use demands (equations 9 and 10) is estimated for singles and couples by means of the Generalized Method of Moments (GMM), assuming intra-group correlation, i.e. that the error terms are correlated across activities within households but uncorrelated across households.[13]

To allow for adding-up the first activities, sleeping was dropped and the remaining (n-1) activities (personal care, household work, 'pure' leisure and commuting), were then estimated. Personal care is considered assignable, that is as a purely private observable time with $\alpha_1 = 0$. Socio-demographic controls include household net non-labor market weekly income, age, age squared, education, a dummy variable for house ownership, car availability, and four regional dummies. In couple estimations, sets of female and male socio-demographics are included in spite of the high correlation within couples, since we assume that the time allocation of each household member depends on both sets of individual characteristics.

12. It is worth noting that these are valued at market prices $p = 1$.
13. GMM estimators are efficient even when there is heteroskedasticity of unknown form (which is not the case with 3SLS). The Pagan and Hall test for the presence of heteroskedasticity confirms that GMM is called for.

As both spare time and full income depend on working hours, they could be endogenous. Hence, the household full-income is estimated using two distribution factors: the female-to-male ratios of wages and qualifications.

Regarding spare time, a natural instrument for working hours and, therefore time resources, is wage rate since it is considered to be an opportunity cost leading to the choice of working hours. Under separability it should not be related to the other uses of time. However, BROWNING and MEGHIR [1991] note that the use of wage as an instrument can lead to difficulties. Beyond the selection problem, which refers to the observability of wages for workers only, wage could be endogenous, due to measurement error, an omitted variable or reverse causality. As the average hourly wage is computed as the quotient of weekly earnings over weekly working hours, any measurement error would introduce a spurious negative correlation between this instrument and the endogenous variable, namely labor supply (MROZ [1987]). In addition, household work and child care could be bought on the market, especially for individuals with a higher opportunity cost of leisure. Moreover, if the price of some activities, like commuting, correlates with wages, elasticity estimations could be biased. Finally, wages weakly correlate with the number of working hours, because, in the medium term, the labor market is often characterized by labor contracts defined in terms of a wage-hours package.

Given these problems, we use an alternative set of instruments for spare time, which are correlated both with wages and working hours. Indeed, using job characteristics appears to be more robust. The complete set of instruments are: demographics, managerial responsibilities, shift work and the local unemployment rate. Good instruments should be both relevant and valid, that is correlated with the endogenous regressors and orthogonal to the errors. To check the relevance and the validity of our instrumental strategy, several tests were performed. The first stage of instrumentation is observed, to (i) determine the correlation between instruments, the endogenous and dependent variables for validity purposes, and (ii) to confirm the endogeneity of the variable of interest i.e. time resources. The Durbin-Wu-Hausman tests reject the exogeneity of time resources for each activity by gender. Furthermore, the instruments correlate with the endogenous variable though uncorrelated with the dependent ones.

The F-statistic tests reject the weakness of our instrument sets.[14] For single females, single males and couples, the test does not reject the over-identification, meaning that the model is valid. Thus the Hansen-Sargan tests of over-identification do not reject the validity of our full set of instruments at the 5% level. For singles, the $\chi^2(31)$ is 42.1 for females and 43.7 for males. For couples, the $\chi^2(60)$ is 80.2. It is worth noticing that for singles, the over-identifying restriction tests correspond implicitly to the tests for homogeneity and symmetry restrictions.

IV.3. *Separability Tests*

A simple test of weak separability consists of testing whether the time-demands t_i^k depend on the medium-run choices (quantities of goods purchased, C_i). To check this dependency, we use general functional semi-parametric shape for time-use demands G. We model G using a

14. One rule of thumb is that an F-statistic below 10 is cause for concern about an instruments weakness (STAIGER and STOCK [1997]). Here, the F-statistic is equal to 16.6 for female and 18.46 for male, and so confirms the relevance of our instrument set.

flexible second-order polynomial of $\widetilde{T}$, consumption C and demographics X (age, age squared, education, region and house-ownership):

$$G_2(\widetilde{T}, C, \mathbf{x}, \alpha) = \alpha_0 + \alpha_1 \widetilde{T} + \alpha_2 C + \alpha_3 \mathbf{x} + \alpha_4 \widetilde{T}^2 + \alpha_5 C^2 + \alpha_6 \mathbf{x}^2 + \alpha_7 C * \widetilde{T} + \alpha_8 C * \mathbf{x}$$

With the polynomial shape of our functional form, all we have to do is test whether the marginal effect of consumption on time-use is zero for all individuals i. If the null hypothesis, *i.e.*, that the marginal effect of consumption on time-use demand is zero is rejected, it would be statistical evidence against our separability assumption. We use the total net household weekly income to proxy consumption. As the consumption, C, is endogenous, we use instruments that mainly explain hours of work and mainly belong to the employment characteristics: non-labor income, wage, a dummy variable if individual works full-time, and the interaction between them.

TABLE II. – Separability Tests

	Single female	Single male	Female in couple	Male in couple
Personal care	−0.06 (−0.2)	−0.09 (−0.56)	−0.09** (−2.39)	−0.05 −1.21
Housework	−0.54 (−1.15)	0.22 (0.95)	−0.05 (−0.73)	0.13** (2.4)
Leisure	0.92 (1.83)	−0.4 (−1.24)	−0.07 (−1.15)	−0.01 (−0.01)
Commuting	−0.005 (−0.02)	−0.09 (−0.45)	−0.01 (−0.33)	−0.02 (−0.63)

Marginal effect. t statistic in parentheses. ** significant at the 5% level.

TABLE II presents the separability tests. The marginal effects of consumption expenditures on time-use demands for each time-use activity presented here are evaluated at sample means. Observing the estimates of the total net household weekly income on time-demands, we see that some of them are significant: the impacts on personal care for females in a couple and on housework for males in a couple. We conclude that separability between consumption and the daily time-allocation assumption is rejected for couples but not for singles. For couples, rejection of separability could be linked to a non-separable utility function or to a non-separable time-technology function. To take into account the rejection of separability, we adopt a conditional approach without separability by adding household consumption in covariates into the time-use technology function:

$$\alpha_i^k = \alpha_i^k(\mathbf{x}_i, C) \tag{12}$$

The interpretation is interesting since C , or a share of C, can be interpreted as buying market substitutes for time.

IV.4. *Results*

First, this section deals with estimation of single females and single males in order to recover the preference parameters. TABLE III shows the ρ parameters of the Stone-Geary welfare function.[15] They are computed for the average non-labor income, age, age squared, education,

15. The estimation results are presented in the Appendix in TABLE B.1.

house-ownership, car availability, and regional dummies. These coefficients correspond to the marginal share of each non-market activity in individuals' spare time. A significant proportion of spare time is devoted to leisure: 42% for females and 43% for males. Women seem to somehow voluntarily choose to devote more time to housework: women spend 29% on their spare time in household tasks while men spend about 17%. This suggests that women have a higher preference for the commodity produced with housework or a lower disutility of time spent working at household chores.

TABLE III. – Preference Parameters

	Single Female	Single Male
Personal Care	0.079** (0.0323)	0.085*** (0.0255)
Housework	0.285*** (0.0467)	0.168*** (0.0355)
Leisure	0.424*** (0.0534)	0.431*** (0.0504)
Commuting	0.02** (0.0092)	0.068** (0.0304)
Sleeping	0.192	0.248

Note that due to adding-up restriction, time devoted to sleeping is not estimated. The proportion of spare time devoted to sleeping is computed as follow: $1-\Sigma_{k=1}^{4}\rho k$. Absolute standard errors are in parentheses.
*, **, *** significant at the 10, 5 and 1% level.

TABLE IV shows the estimated parameters of the time-use technology function α.[16] Since we include heterogeneity in the time-use technology parameters, results are estimated for the sample average. Results surprisingly suggest that time externalities generated by leisure seems to be much more important than those generated by housework. Hence, we could deduce that the welfare gains linked with time-use are probably more related to externalities in terms of welfare (enjoyment of jointness of leisure activities), and less related to the productive aspect of life in a couple (household production), for the sample average.[17]

TABLE IV. – Time-Use Technology Function Estimation and Lindahl Prices

	α	π_f	π_m
Housework	0.08** (0.039)	5.08*** (0.33)	5.37*** (0.77)
Leisure	0.22** (0.088)	4.08*** (0.733)	4.61*** (0.773)
Commuting	0.08** (0.038)	20.31*** (5.088)	27.92*** (5.471)

Standard errors are in parentheses. **,*** significant at the 5 and 1% level.

Lindahl prices are also estimated in their reduced form. TABLE IV presents the π estimates.[18] They correspond to the price of the private time equivalent within the household. Female Lindahl prices are lower than those of males, for all activities. This suggests that, on average, women purchase private time equivalents more cheaply than do men within the

16. The estimation results are presented in the Appendix in TABLE B.2.
17. It is worth indicating that the reverse could be observed for some given household characteristics.
18. The estimation results are presented in TABLE B.2 in the Appendix.

household.[19] This could be related to the fact that the valuation of time decreases with the quantity of spare time which is on average higher for females. Taking into account economies of scale linked with life in a couple suggests that one hour devoted to housework or leisure purchased within the household is cheaper than its relative opportunity cost. In other words, time spent outside the labor market costs less than what the individual would earn by supplying this time on the labor market.

TABLE V. – Economies and Indifference Scales

	For 2 singles	
Economies of Scale (% of household spare time)	0.063	(0.074)
Economies of Scale (minutes)	135.60	(158.202)
Female Indifference Scale (% of household spare time)	0.54	(0.049)
Male Indifference Scale (% of household spare time)	0.52	(0.055)

Standard deviation are in parentheses.Computed at the average mean of the sample.

The overall scale-economy measure (TABLE V) indicates that two singles living apart need 6.3% more time to achieve the same utility level as living in a couple, while maintaining the same preferences. A couple saves 2 hours and 15 minuts a day by living together. This estimation of economies of scale is an upper bound because differences between market and shadow prices suggest that singles can re-allocate time and thus more cheaply attain the same indifference curves: a single woman (man) requires 55% (52%) of joint time resources to be as well off as if she (he) lived in a couple.

TABLE VI. – Economies of Scale by Activity and Household Member

	Female	Male
Housework (% of time devoted to)	0.13	0.21
minutes	22.13	17.49
Leisure (% of time devoted to)	0.31	0.22
minutes	71.82	58.71
Commuting (% of time devoted to)	0.09	0.13
minutes	8.31	6.95

Computed at the average mean of the sample.

Next, economies of scale by activity and household member are presented in TABLE VI. Living in a couple allows individuals to save time. A female, on average, gains 22 minutes of time devoted to housework, 72 minutes of leisure and 8 minutes of commuting per day. Living with his wife gives rise to economies of scale for a married male: 20 minutes saved in housework, 60 minutes of leisure and 7 minutes of commuting to attain the same level of well-being. Obviously, the time savings depend on the characteristics of the couple, and so some wives may actually lose time by living with their partners.

Interestingly, for a given Pareto weight and preferences for the average sample, women save more time than their partners by living in a couple. This could be explained by sample characteristics. Actually, first, women have on average more spare time than men. Second,

19. This is only true for the sample average of socio-demographics variables. For some couples, the opposite is observed.

single females spend much more time on housework than single males, this induces in the estimation higher female housework needs, or higher female preference for the commodity good produced with housework time. This gender difference in housework preferences drives the result.[20] Preference and technology parameters imply that women save more time by forming a couple. Therefore, after dissolution of the couple, women require more compensation since they lose more welfare than men. When considering descriptive statistics, even if women are richer than men in terms of spare time, they enjoy less 'pure' leisure if we consider both paid and unpaid work. However, this welfare analysis suggests that women benefit more than men from economies of scale in time-use generated by the formation of a couple.

Finally, we define time-poverty lines. The definition of time poverty follows basically the same kind of arguments as the definition of money poverty. However, unlike monetary poverty that is based on nutritional requirements, there is not scientific definition of "needs" in time. Hence, we translate poverty lines developed in CHERCHYE, DE ROCK, and VERMEULEN [2012] to the case of time metric. We compute time equivalents for people living in a couple and then compute the median of the distribution of times (spare time, i.e. 1,440 minutes minus time spent working on the labor market for singles, and time equivalents for individuals who live in a couple). Individuals with less than 60% of median equivalent time expenditures are considered to be time-poor. Hence, the time-poverty line is around 15 hours per individual a day, that is working more than 60 hours a week.[21] This includes 3% of our sample, covering workers living alone or with their partners but without children or anybody else in the household.

V. Conclusion

This paper models and estimates equivalence scales and economies of scale in time-use based on UK data. Our framework, inspired by BROWNING, CHIAPPORI, and LEWBEL [2013], overcomes previous methodological shortcomings. The same individual time-use demands are compared in different marital situations. Welfare wastes or gains are defined in terms of time for each household member.

The results however must be taken with caution since they rely on parametric assumptions, and the sub-sample is restricted to singles and couples without children. Still, they bring important insights into how time-use and intra-household bargaining could affect welfare analysis. Two singles living apart require 2 hours and 15 minutes more spare time a day to achieve the same utility level as when living in a couple. On average, the welfare derived from individual time-use activities tends to be increased by living in a couple. We also demonstrated that welfare interactions in time-use are high, even when considering "pure" leisure.

Interestingly, a single woman requires 55% of the couple time-resources to be as well-off as when living in a couple. Individuals can benefit unequally from economies of scales. On average women enjoy greater benefits than men as they save more time by living in a couple. This result could be due to the way heterogeneity is introduced into the analysis, since time needs can vary across time-categories and gender.

20. Gender differences in tastes are recognized to be a social construct. One could therefore question whether it makes sense to maintain this difference in a gender welfare analysis. Whether we should put a veil of ignorance upstream or downstream of some observed characteristics – such as gender – is an ethical choice that we did not consider here.
21. Remind that is an average for working and non-working day.

The time-poverty line is about 15 hours per individual per day. Using a time metric to observe inequalities has a main advantage: it does not require any reference to wage rates, and hence the valuation of time of two single individuals is taken as identical. This could be viewed as a correct ethical view but it is also a drawback. Since time is not transferable and consumption is ruled out from the analysis. As a consequence there is no way of providing a compensation for these observed time inequalities.

To be fully operational from a policy perspective, a more complete economic model should simultaneously consider monetary and time poverty, as well as potential substitution channels between consumption of goods and time-use. Considerable reflexion about the implicit ethical assumptions in such a framework would also be necessary. We could then move from a purely material redistributive aim to a broadly redistributive aim including the assessment of spare time.

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Appendix

A. Individual Lindahl Prices

Centralized household daily time-allocation program for allocation of time-uses **t** and commodities **z** is:

$$\max_{\mathbf{z}_f,\mathbf{z}_m,\mathbf{t}_f,\mathbf{t}_m} \mu(.).U_f\left(\mathbf{z}_f\right)+U_m(\mathbf{z}_m)$$
$$\begin{cases} \text{st. } \Sigma_{k=1}^{K} t_i^k = \widetilde{T}_i \\ \text{st. } \begin{matrix} z_f^k = t_f^k + \alpha^k t_m^k \\ z_m^k = t_m^k + \alpha^k t_f^k \end{matrix} \\ \text{st. } t_i^k \geq 0, t_i^k \leq T \text{ for } i = f,m \text{ and } k = 1,...K \end{cases} \tag{A.1}$$

where $\widetilde{T_i}$ is spare time computed by substracting hours of labor market work to daily time endowment. We remind that bold letters refer to the vector whereas normal letters refer to each component of the vector. Notice that the time constraint is also a time-budget constraint so $\sum t_i^k = \widetilde{T_i} \Leftrightarrow w_i \sum t_i^k = w_i \widetilde{T_i} = \widetilde{FI}$ where $\widetilde{FI}$ is the full-income conditional on medium run choices (full income minus medium run consumption).

The time publicness parameter is such that $\alpha^k \in]0;1[$. Inverting time-use technology function (equation 1) leads to the following relationship between time devoted to each activities and their private equivalent bundles :

$$\begin{cases} t_f^k = \frac{z_f^k - \alpha^k z_m^k}{1-(\alpha^k)^2} \\ t_m^k = \frac{z_m^k - \alpha^k z_f^k}{1-(\alpha^k)^2} \end{cases} \text{, for } k = 1, ..., K \tag{A.2}$$

Substituting equation (A.2) the two time-budget constraints of program above leads to the new constraints and program:

$$\begin{array}{l} \max_{\mathbf{z}_f, \mathbf{z}_m} \mu . U_f\left(\mathbf{z}_f\right) + U_m(\mathbf{z}_m) \\ \text{st.} \begin{cases} 1 - \Sigma_{k=1}^K \left[\frac{z_f^k - \alpha^k z_m^k}{\widetilde{T_f}(1-(\alpha^k)^2)} \right] = 0 \\ 1 - \Sigma_{k=1}^K \left[\frac{z_m^k - \alpha^k z_f^k}{\widetilde{T_m}(1-(\alpha^k)^2)} \right] = 0 \end{cases} \end{array} \tag{A.3}$$

We denote λ_f and λ_m the Lagrangian multipliers associated to the constraints in the program above.

Necessary conditions are:

$$\begin{cases} \mu \frac{\partial u_f}{\partial z_f^k} = \frac{\lambda_f}{\widetilde{T_f}(1-(\alpha^k)^2)} - \frac{\lambda_m \alpha^k}{\widetilde{T_m}(1-(\alpha^k)^2)} \\ \frac{\partial u_m}{\partial z_m^k} = \frac{\lambda_m}{\widetilde{T_m}(1-(\alpha^k)^2)} - \frac{\lambda_f \alpha^k}{\widetilde{T_f}(1-(\alpha^k)^2)} \end{cases} \tag{A.4}$$

We now define the following dual Program, that leads to the same commodity demands:

$$\begin{array}{l} \max_{\mathbf{z}_i} \ \mu U_f\left(\mathbf{z}_f\right) + U_m\left(\mathbf{z}_f\right) \\ \begin{cases} \text{st. } 1 - \Sigma_{k=1}^K \frac{\pi_i^k}{\eta_i} z_i^k = 0 \\ \text{for } i = f, m \end{cases} \end{array} \tag{A.5}$$

where π are the individual implicit evaluations of each commodity, η_i is the individual sharing rule.

Necessary conditions of dual program (P^d) are:

$$\begin{cases} \mu \frac{\partial U_f}{\partial z_f^k} = \lambda_f \frac{\pi_f^k}{\eta_f} \\ \frac{\partial U_m}{\partial z_m^k} = \lambda_m \frac{\pi_m^k}{\eta_m} \end{cases} \tag{A.6}$$

Equalizing necessary conditions of P^c and P^d (equations A.4 and A.6) gives:

$$\begin{cases} \frac{\pi_f^k}{\eta_f} = \frac{\lambda_f T_m - \lambda_m T_f \alpha^k}{\lambda_f T_f T_m \left[1-\left(\alpha^k\right)^2\right]} \\ \frac{\pi_m^k}{\eta_m} = \frac{\lambda_m T_f - \lambda_f T_m \alpha^k}{\lambda_m T_f T_m \left[1-\left(\alpha^k\right)^2\right]} \end{cases} \tag{A.7}$$

B. Estimation Results

TABLE B.1. – Single Estimations

	Personal Care		Housework		Leisure		Commuting		Spare Time	
Single female										
Constant	0.082	0.037	0.200	0.062	0.488	0.059	0.010	0.0345	1,102.912	12.353
Age	0.000	0.001	0.002	0.002	−0.002	0.002	0.000	0.001		
Age squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Education	0.001	0.001	−0.001	0.001	0.000	0.001	0.001	0.000		
Region	0.006	0.004	0.001	0.007	−0.016	0.008	0.005	0.004		
House Ownership	0.002	0.004	−0.001	0.005	0.003	0.006	0.001	0.003		
Non-labor income									0.555	0.182
Manage									−35.936	15.766
R-squared	0.38		0.36		0.37		0.33		0.3	
Observation					156					
Single male										
Constant	0.077	0.035	0.134	0.049	0.414	0.0703	0.042	0.043	1046.932	13.556
Age	−0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.001		
Age squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Education	0.002	0.001	−0.001	0.001	−0.002	0.002	0.001	0.001		
Region	0.007	0.067	−0.019	0.008	0.014	0.011	0.005	0.006		
House Ownership	0.000	0.004	0.010	0.006	−0.014	0.009	0.010	0.005		
Non-labor income									0.970	0.243
Manage									−15.329	5.818
R-squared	0.33		0.3		0.36		0.33		0.34	
Observation					193					

Note that due to adding-up restriction, time devoted to sleeping is not estimated. Absolute standard errors are in parentheses.

TABLE B.2. – Couple Estimations

	α^2			α^3	α^4	
Constant	−86.84	(36.321)	6.09	(2.647)	−327.78	(142.111)
Female Age	0.45	(0.194)	0.05	(0.0214)	28.94	(11.408)
Female Age squared	0.00	(0.001)	0.00	(0.000)	−0.63	(0.242)
Female Education	5.52	(2.33)	−0.47	(0.254)	1.24	(0.538)
Male Age	−0.10	(0.039)	0.00	(0.001)	−0.03	(0.012)
Male Age squared	2.11	(0.961)	0.08	(0.036)	−0.27	(0.116)
Male Education	0.24	(0.103)	−0.16	(−0.068)	−1.48	(0.352)
Consumption	−0.04	(0.011)	0.00	(0.001)	−0.02	(0.009)
			Female Full Income		Male Full Income	
Constant			53.42	(11.545)	163.23	(29.237)
Education ratio			17.96	(3.914)	1.77	(0.769)
Wage ratio			0.41	(0.027)	−1.57	(0.096)
Partner's Spare time			0.02	(0.010)	0.11	(0.054)
Non-labor income			0.04	(0.010)	−0.03	(0.011)
	π_f^2		π_f^3		π_f^4	
Constant	−0.13	(0.040)	−0.04	(0.017)	2.47	(0.840)
Female Age	0.00	(0.001)	0.00	(0.001)	−0.16	(0.045)
Female Age squared	0.00	(0.001)	0.00	(0.001)	0.00	(0.001)
Male Age	0.01	(0.002)	0.00	(0.001)	0.04	(0.008)
Male Age squared	0.00	(0.001)	0.00	(0.001)	0.00	(0.001)
Education ratio	0.03	(0.005)	0.02	(0.005)	0.04	(0.018)
Wage ratio	0.00	(0.001)	0.00	(0.001)	0.00	(0.001)
	π_m^2		π_m^3		π_m^4	
Constant	10.25	(1.460)	5.50	(0.928)	111.00	(17.752)
Female Age	−0.56	(0.079)	−0.39	(0.056)	−8.89	(1.420)
Female Age squared	0.01	(0.001)	0.01	(0.001)	0.17	(0.026)
Male Age	0.002	(0.001)	0.05	(0.018)	0.94	(0.154)
Male Age squared	−0.004	(0.001)	−0.01	(0.001)	−0.01	(0.002)
Education ratio	0.40	(0.055)	0.28	(0.037)	2.89	(0.456)
Wage ratio	−0.89	(0.126)	−0.45	(0.045)	−6.78	(1.163)

Absolute standard errors are in parentheses.

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