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

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Abstract

How does within couples’ time-use interactions generate welfare in the family? In this paper we model economies of scale in time use. Following Browning et al. (2013), we allow intra-household bargaining power to affect the distribution of welfare gains in the family. We estimate the model using the UK Time Use Survey (2000). Results suggest that two singles living apart need about 2h15 more to achieve the same utility level as when living in a couple. A single woman requires on average 55% of the couple time-resources to be as well-off as when she lived in a couple. The time-poverty line is on average 15 hours per individual a day.

Abstract

Comment l’utilisation du temps dans une interaction de couple peut-elle générer des gains de bien-être ? Ce modèle estime les économies d’échelle et les échelles d’équivalence en termes de temps. Inspiré de Browning et al. (2013), la répartition intra-familiale des pouvoirs de négociation affectent la répartition des gains de bien-être au sein du ménage. Utilisant l’enquête sur l’utilisation du temps au Royaume-Uni en 2000, les résultats suggèrent que deux célibataires ont besoin de 2h15 supplémentaire par jour pour atteindre le niveau d’utilité qu’ils auraient en vivant en couple. Ainsi, une femme a besoin en moyenne de 55% du temps libre du couple pour atteindre le même niveau de bien-être. Le seuil de pauvreté en termes de temps est de 15h par jour et par individu.

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1 Introduction

Equivalence scales are widely used to make interpersonal welfare comparisons of households of different sizes, compositions or characteristics. They allow converting observed expenditures of different types of households in comparable units (Lechene (1993), Banks et al. (1997)). They result from economies of scale, that is cost advantages of couple in comparison to two singles living apart. For example, sharing the accommodation, heating and so forth generates economies of scale and welfare gains that could be measured using equivalence scales. These gains vary depending on household composition and income. They are widely applied to define poverty lines. Traditionally, welfare level is exclusively defined on a good consumption basis (Nelson (1993)). However, the disposition 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 individual has time. Sociologists argue that life satisfaction have temporal aspects as ‘spare time’ and ‘discretionary time’ affect individual’s subjective well-being (Eriksson et al. (2007)). Time-poverty is a concept that is of growing interest in the literature (Vicker (1977), Goodin et al. (2005), Hamermesh & Lee (2007)).

In this paper, we estimate a household’s time allocation model that allows identifying economies of scale in the time allocation process of the 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 answering the following questions : “How much time does a 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 couple means saving time, because, for example, cooking for two does not require twice more time than cooking for one. Thus, living together and sharing create economies of scale within household, meaning that a widow needs more spare time than what she has to achieve the same welfare she had once living in a couple. To our knowledge, except Van Hoa & Ironmonger (1989) there is no such attempt in the economic literature.

In the poverty analysis undertaken here, individual time is considered as the unique source of utility. While daily time endowments are identical across individuals, their freedom to allocate time to non-market activities differ. 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 (1985)’s capability concept and has a crucial impact on well-being. We consider that, on a daily perspective, the time spent on the labor market is the most constrained one whereas the other types of time-use categories (housework, sleeping or leisure) could be allocated.

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, the model provided here is a stepping stone to achieve this.

\footnote{Eriksson et al. (2007) define ‘spare time’ as the amount of time which remains after actually spending time in paid labor; ‘discretionary time’ as the amount of time under which individuals have control. Here, we do not distinguish the two concepts.}
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 an 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 his/her 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 different types of individuals in different household composition contexts.

From a methodological point of view, this paper follows the literature solving theoretical controversies regarding equivalence scales definition. 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 this aim, utility cardinalization is required, which was widely criticized (see Pollak & Wales (1979, 1995), Gronau (1988), Nelson (1988), Browning et al. (2013) for more details). Second, traditional definition assumes that within households, welfare levels are equalized (Nelson (1993)). Recently, Browning et al. (2013) (BCL hereafter) 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 equivalence scale that maintains ordinality of utilities and hence is free from such drawback. BCL estimate adult-indifference scales. To this aim they defined individual equivalent incomes that 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, allowing analyzing the possible intra-household variation in the standard of living.

BCL analysis is based on a collective representation of household decision-making process. The household is the scene of bargaining process among its members, where the sharing rule characterizes the bargaining power of each member (Browning et al. (2013), Apps & Rees (1988), Browning & Chiappori (1998), Vermeulen (2002), Chiappori & Donni (2006), Fortin & Lacroix (1997)). In this case, household utility function is defined as a weighted sum of family members individual sub-utility functions. Household behavior is also Pareto-efficient. To capture economies of scale in consumption, BCL introduce a consumption technology function that characterizes the intra-household publicness of goods consumption or positive externalities associated with the consumption of goods within the household. Cherchye et al. (2012) use the BCL framework to analyze economic well-being and poverty among elderly.

Vermeulen & Watteyne (2006) and Lewbel & Pendakur (2008) provide an alter-
native specification that eases identification. Vermeulen & Watteyne (2006) propose to give up the consumption technology function. They define a priori goods that are privately consumed and those which are publicly consumed. Lewbel & Pendakur (2008) and Bargain & Donni (2012) provide a model relying on Engel curves estimates, without price variation. Thus, Bargain & Donni (2012) defined a new concept of child cost using this framework.

Our model brings new elements to this framework. We introduce a time-use technology function that reflects intra-household economies of scales in time. The links between good and time consumption are clarified thanks to a time separability assumption tested in the empirical part. Our contribution brings a first stone in the building of a complete model of intra-household welfare interaction due to consumption and leisure. We apply the model to UK time-use data. Results show that two singles living apart need 2h15 hours more spare time to achieve the same utility level as living in couple. A single woman requires 54% of joint time-resources to attain the same utility level than she would have when she lived in a couple and men 52%. Time-poverty lines are also defined. 3% of our sample is considered as time-poor, that is having less than 15 hours spare time a day.

This paper proceeds as follows. Section 2 presents the theoretical model; Section 3 then presents the identification strategy and Section 4 the empirical framework and results. Last, Section 5 concludes.

2 Household’s Daily Time allocation Choice

We present the model under a separability assumption which requires that hours of work and consumption do not impact daily time allocation, except through an income effect. In this model, time-use allocation decision is analyzed 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. We focus on dual-earner full-time working couples or single individuals without children.\(^3\)

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 can denote “time inequalities”. Spare time, \(\tilde{T}\), 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 across 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, the usual worker receives his wage and salary every month. The labor contract defining wages and working hours is often signed for a longer time period. Working hours can evolve for shorter time periods, but this might mostly come from the employer’s side to insure 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 \(z\)) : \(U_i(z_i)\). These commodities \(z\) are generated by a production process that uses time

\(^3\)The inclusion of children raises additional identification issues. Are children decision-makers? How does the welfare of children interact with their parents? How does productive behavior of children interact in the household production process?
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.

2.1 Time-use Technology Function

The time-use technology function describes how time inputs are transformed into time private equivalents that enter in the welfare functions of household members. It has two implications. First, it allows introducing heterogeneity in the abilities to transform time-use into welfare. Second, it allows understanding how couple life generate 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 et al. (2013) and Cherchye et al. (2012)).

Let \( z_i = (z_i^1, z_i^2, \ldots, z_i^K) \) be a vector of time private equivalents, while \( t_i = (t_i^1, t_i^2, \ldots, t_i^K) \) 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 \( z_i \) is assumed to be linearly produced within the household using its members’ uses of time: \( z = z_f + z_m = F(t_f, t_m) \), the \( F \) function having the following property:

\[
\frac{\partial^2 F_i}{\partial t_k \partial t_{k'}} = 0.
\]

In single households, there is no economies of scale, the different time-use activities are directly considered as commodities entering in the individual utility function: \( z_i = t_i \).

The interpretation of the relationship, \( F \), is twofold. On one hand, it can simply be viewed as a household production process with constant returns to scale and perfect substitutability of time-use activities within the household and across activities. In this view, commodities produced by the household are assignable to household members. The process describes how an aggregate private good commodity vector \( z = z_f + z_m \) is produced at the household level and then shared amongst household’s members. Production of a diner could easily enter in this category.

On the other hand, it can be viewed as a time-use generalization of the consumption technology function. The consumption technology function proposed by BCL transforms household effective purchases into private good equivalent bundles. The time-use technology function transforms time effectively spent \( t_i \) into private time equivalent \( z_i \). It allows defining equivalence scale on an individual basis (denoted adult indifference scales). It also describes how time-use externalities induced by family status (being single or in couple) impacts individual welfare. This interpretation corresponds to leisure activities, as playing tennis together for example. As noted by Browning et al. (2013), contrary to the Becker’s domestic production function, the technology function implies 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 jointness of non-market activities.

Overall, the \( F \) function summarizes how welfare in time is generated by 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 his/her partner).\(^4\)

\(^4\)To ease interpretation and estimation, the specification does not allow any externality across...
The specification of $F$ can be simply written in the following way:

$$
\begin{align*}
z_k^f &= t_k^f + \alpha_k t_m^k, \\
z_m^k &= t_m^k + \alpha_k t_f^k,
\end{align*}
$$

(1)

for $k = 1, ..., K$.

$\alpha_k$ 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.\(^5\) The lower $\alpha_k$, the more private the $k^{th}$ non-market activity. The private equivalent of woman living in a couple, $z_k^f$, is composed by the time spent by this woman in activity $k$, $t_k^f$ plus the public part of the time spent by his partner $m$ to this same activity $k$, $(\alpha_k t_m^k)$.

### 2.2 Time-use Demand for Singles

We first describe the behavior of single households. For sake of simplicity the household’s subscript is omitted. According to our separability assumption, the medium run choices do only impact the time-uses 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 $t = (t^1, ..., t^K)$ the individual time-use vector and $\tilde{T}$ the spare time endowment:

$$
\max_{t^i} U_i (t^i)
$$

(Ps)

$$
\begin{align*}
st. & \sum_{k=1}^K t_i^k = \tilde{T}_i \\
st. & t_i^k \geq 0, t_i^k \leq T
\end{align*}
$$

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

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

(2)

Daily time-use demands are identical to the commodity demand since $t_i = z_i$. 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 the short run spare time $\tilde{T}$ varies across individuals, it is possible to identify these elasticities under some parametric restrictions described later in the text.

### 2.3 Commodities and Time-use Demand for Couples

Couple’s daily allocation of time is supposed to follow a collective model (Apps & Rees (1988), Browning et al. (1994)). Time allocation in the short run (i.e. on a daily basis) is assumed to be efficient and taken conditional on medium run consumption and labor supply choices. For the couple, individuals time-constraints are $\sum_{k=1}^K t_f^k = \tilde{T}_f$ and $\sum_{k=1}^K t_m^k = \tilde{T}_m$. Therefore, household daily time-allocation program ($P_c$) is for the case of couples:

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.

\(^5\)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.
\[
\max_{z_f, z_m, t_f, t_m, \mu(\cdot)} U_f(z_f) + U_m(z_m)
\begin{align*}
st. \sum_{k=1}^{K} t^k_i &= T_i \\
t_f^k &= t_f^k + \alpha k t^k_m \\
z^k_m &= t^k_m + \alpha k t^k_f \\
\text{st. } t_i^k \geq 0, t_i^k \leq T \text{ for } i = f, m \text{ and } k = 1, \ldots, K
\end{align*}
\] (Pc)

The Pareto weight $\mu$ generally depends on prices, incomes and eventually distribution factors\(^6\). It reflects the weight of individual sub-utility in the household decision-making process.

We now focus on interior solutions.\(^7\) To this aim, broad definitions of type activities will be chosen in order to make sure that all household members do spend a positive amount of their time in each of them.

Solutions of program $(P_c)$ can be rewritten as solution of an individual decentralized program $(P_d)$:

\[
\max_{z_i} U_i(z_i)
\begin{align*}
st. \sum_{k=1}^{K} \pi^k_{i} z^k_i &= \eta_i
\end{align*}
\] (Pd)

In the decentralized case, the sharing rule $\eta$ 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 $\pi$, that itself depends on how economies of scales in time are generated in the household. Pareto weights and sharing rule refer both to the bargaining power in the decision process: higher is the weight $\mu$ and the sharing rule $\eta_f$, greater are the private time equivalent consumed by the female individual $z^f_f$. 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 $U_m$, contrary to the Pareto weight $\mu$.

Because of the separability assumption between 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 of second step income in a two-step budgeting procedure). If separability does not hold, then efficiency at the sub-level cannot be guaranteed (Blundell et al. (2005)). As a consequence, prices related to medium-run choices (wage rates) impact decision 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):

\[
\begin{align*}
\pi^k_f &= \frac{\lambda_f T_m - \lambda_m T_f n^k}{\lambda_f T_f T_m [1 - (\alpha k)^2]} \eta_f \\
\pi^k_m &= \frac{\lambda_m T_f - \lambda_f T_m n^k}{\lambda_m T_f T_m [1 - (\alpha k)^2]} \eta_m
\end{align*}
\] (3)

\(^6\)A distribution factor is a variable that affects bargaining power but not preferences of individual household members or the joint budget set.

\(^7\)Extending the empirical approach to corner solutions would allow considering a greater number of time-use activities. However, this extension in a structural daily time-use allocation case is not straightforward. In structural collective models, considering non-participation of labor supply choices is now relatively standard (Donni (2009), Bloemen (2010)), it 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 & Bonke (2006)). Given the novelty of the approach undertaken here, we keep this problem for further research.
where $\lambda_i$ is the Lagrangian multiplier associated with the individual time-constraint which represents the opportunity cost of domestic time for the household member $i$.

Unlike BCL, in our case, individual shadow prices do vary within the household meaning that individuals have different marginal valuation for the activities. It is worthy indicating that the individual perception (implicit cost) of time-uses varies because of the time saving technology ($\alpha^k$). The higher 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 $z_i$ are obtained for program (Pc) or (Pd):

$$z^k_i = h^k_i(\pi_1^i, ..., \pi^K_i, \eta_i) \quad (4)$$

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

$$\begin{align*}
t^f_k &= \frac{1}{1-(\alpha^k)^2} h^f_k(\pi_f, \eta_f) - \frac{\alpha^k}{1-(\alpha^k)^2} h^m_k(\pi_m, \eta_f) \\
t^m_k &= \frac{1}{1-(\alpha^k)^2} h^m_k(\pi_m, \eta_m) - \frac{\alpha^k}{1-(\alpha^k)^2} h^f_k(\pi_f, \eta_m)
\end{align*} \quad (5)$$

3 Identification strategy

First, we define the reduced form time-use demands of couple that only depends on observables $\bar{T}_i$ as well as observed heterogeneity variables $x$:

$$\begin{align*}
t^f_k &= t^f_k(\bar{T}_f, \bar{T}_m, x) \\
t^m_k &= t^m_k(\bar{T}_f, \bar{T}_m, x)
\end{align*} \quad (6)$$

Structural time-use demands are defined above in equation (5). They depend on commodity demands of both couple members, $h_f$ and $h_m$, and on parameters of the time-use technology function, $\alpha^k$. Commodity demands depend themselves of shadow prices $\pi_f$ and $\pi_m$ that were derived in the preceding section. These prices are themselves a known function of observables as well as parameters of interest $\alpha$ and Lagrangian multipliers $\lambda_f, \lambda_m$ which represents 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, as well as the intra-household sharing rule (equation 5) from the observation of a time-use demand for singles and couples (equations 6 and 2)? To this aim, some 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 on singles. Third, the individual share of commodity is proportional to his 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 controversial, is common in the literature (Couprie (2007), Bargain & Donni (2012), Lewbel & Pendakur (2008), Lise & Seitz (2007)).
When you think about reasons why this assumption might not hold (preferences for time might differ across family status), two main reasons come in mind: heterogeneity and welfare interactions. Both reasons are controlled by the model so this assumption is not as strong as it might appear at first sight. First, in the empirical specification, preference heterogeneity is included so this assumption of preference equality is applied conditional on observed characteristics. Second, welfare interactions due to time-use in the family should be adequately controlled for. The time-use technology function does this. Our view is that it is the case that this function adequately summarizes these interactions. However, we recognize that this assumption could be problematic if the marriage or divorce process in itself is related with time-use preferences or time-use interaction in the family, which is a situation that could not 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 problematic since prices remain fixed for singles. So generally, price elasticities of each activity cannot be individually identified. Indeed, if we denote $h$ the structural time-use demand for singles and $\zeta$ the reduced-form one, we have that:

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

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

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

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

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

As is obvious from equation (3), the sharing rule cannot be separately identified from the Lindhal prices. We specify a sharing rule that corresponds to the individual conditional full income: $\eta_i = \bar{FI}_i$. This assumption makes sense. An individual who enjoys more spare time and/or who has a higher wage rate in the household has a higher bargaining power and would be able to extract a higher share of household

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resources regarding time-uses. 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 to 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 & Rees (2001)).

Following BCL and Chiappori & Ekeland (2006) we obtain a generic identification of the model. For \( K \geq 1 \) generic identification of the time-use technology parameters \( \alpha_k \) and the individual opportunity costs \( \lambda_f, \lambda_m \) 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 \( \lambda_f, \lambda_m \) from the observation of the reduced form time-use functions (equation (6))? Hence, 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 \( \alpha \) and the two individual opportunity costs \( \lambda_f, \lambda_m \). Given the sharing rule defined in Assumption 3, this allows recovering the Lindhal prices for all the activities: \( \pi^f_k \) and \( \pi^m_k, k = 1, \ldots K \). Private equivalents can be recovered from equation (1).

### 3.1 Equivalent Income and Indifference Scale

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

Following BCL, we define the relative economies of scale in time-use, \( e \), by:

\[
e = \frac{p'(\sum_{k=1}^{n}(z^k_f + z^k_m) - \tilde{T})}{p'\tilde{T}} = \frac{\sum_{k=1}^{n}(z^k_f + z^k_m)}{\tilde{T}} - 1 \tag{7}
\]

where \( p \) is a vector of one and \( \tilde{T} = \tilde{T}_f + \tilde{T}_m \).

Indifference scales \( IS_i \) represent the fraction of household time resources that a single \( i \) would require to consume the time private equivalents \( z_i \) at market prices. In this case, it allows achieving exactly the same level of utility with the same indifference curve when living in a couple and when living alone:

\[
IS_i = \frac{\min_{z_i^*}(p'z_i^*|u_i(z_i^*) = u_i(z_i))}{p'T} \tag{8}
\]

In expression (8), the numerator corresponds to the minimal time-expenditures spent by single individual to achieve the same welfare level as living in a couple; and the denominator corresponds to couple time-expenditure.

This concept involves the definition of the equivalent time resources, \( T_i^* \), describing the minimum amount of spare time required for consuming the vector of time private equivalent \( z_i \), which allows to attain the same welfare as in a couple:

\[
T_i^* = \sum_{k=1}^{n}(z^k_i) \tag{9}
\]

An single individual would require a proportion \( IS \) of the household total time-resources to be as well off as when living in a couple.
4 Empirical Application

4.1 Data

We use the UK Time Use Survey 2000\(^9\) which measures the amount of time spent on various activities. Respondents are asked to complete two 24-Hours diaries (a working and a non-working day) broken down into ten-minutes slots. We use the weighted mean of the two diaries. Hence, each amount 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.

Our sample contains 1,111 workers between 16 and 65 years old. We sample single females (159), single males (194) and couples (379) with no one else present in the household. Table 1 presents descriptive statistics. The hourly wage rate is computed as the quotient of weekly labor earnings by weekly working hours. Following Browning & 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, this is the opposite for those living in couple. Following the labor economic 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 more educated than other status, whereas cohabiting or married women are less educated and younger than their male counterpart. Our sample includes a high share of homeowner and car-owner.

The spare time is derived by subtracting declared working hours, including work-related training, according to the time use module to 24 hours. It is then allocated between non-market activities. We used the following non-market activities categories: sleeping, personal care and self-maintenance, housework, that is household maintenance, management, shopping for own household, community services and care; leisure, i.e. social and cultural activities and mass media use, and lastly commuting refers to time spent going to work.

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 substantive fraction do not work. Higher flexibility in the female labor contract implies higher heterogeneity within the female spare time than the male one. Moreover, it implies a higher average female spare time than male.

Concerning individual diaries, consistent with the previous findings, women spend more time to sleeping and personal care on average than men. They also perform more housework and have less leisure, especially for women in couple. 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 reporting for some activities. They could reflect infrequency case or preferences. The first case is a statistical artefact whereas the second case is a ‘corner solution’. Browning & Bonke (2006) propose a method to correct for infrequency bias assuming that some zeros are linked

Table 1 – Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Single female</th>
<th>Single male</th>
<th>Female in couple</th>
<th>Male in couple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage</td>
<td>7.07</td>
<td>6.19</td>
<td>5.02</td>
<td>6.90</td>
</tr>
<tr>
<td></td>
<td>(10.65)</td>
<td>(3.90)</td>
<td>(3.27)</td>
<td>(9.74)</td>
</tr>
<tr>
<td>Age</td>
<td>40.27</td>
<td>39.31</td>
<td>41.20</td>
<td>43.25</td>
</tr>
<tr>
<td></td>
<td>(11.12)</td>
<td>(10.93)</td>
<td>(12.35)</td>
<td>(12.45)</td>
</tr>
<tr>
<td>Education</td>
<td>3.77</td>
<td>3.61</td>
<td>3.36</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>(1.84)</td>
<td>(1.98)</td>
<td>(1.87)</td>
<td>(1.93)</td>
</tr>
<tr>
<td>House ownership</td>
<td>0.75</td>
<td>0.64</td>
<td>0.84</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(0.48)</td>
<td>(0.36)</td>
<td>(0.36)</td>
</tr>
<tr>
<td>Car ownership</td>
<td>0.73</td>
<td>0.68</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>(0.45)</td>
<td>(0.47)</td>
<td>(0.26)</td>
<td>(0.26)</td>
</tr>
<tr>
<td>Available Time</td>
<td>1098.77</td>
<td>1054.57</td>
<td>1117.31</td>
<td>1060.26</td>
</tr>
<tr>
<td></td>
<td>(123.60)</td>
<td>(148.32)</td>
<td>(128.09)</td>
<td>(135.10)</td>
</tr>
<tr>
<td>Hours worked</td>
<td>320.49</td>
<td>371.72</td>
<td>309.44</td>
<td>368.99</td>
</tr>
<tr>
<td></td>
<td>(117.97)</td>
<td>(138.84)</td>
<td>(127.05)</td>
<td>(134.59)</td>
</tr>
<tr>
<td>Sleep</td>
<td>493.83</td>
<td>472.71</td>
<td>496.71</td>
<td>479.79</td>
</tr>
<tr>
<td></td>
<td>(73.73)</td>
<td>(88.81)</td>
<td>(68.41)</td>
<td>(75.61)</td>
</tr>
<tr>
<td>Personal care</td>
<td>124.47</td>
<td>109.55</td>
<td>126.66</td>
<td>117.00</td>
</tr>
<tr>
<td></td>
<td>(47.79)</td>
<td>(52.41)</td>
<td>(48.82)</td>
<td>(53.39)</td>
</tr>
<tr>
<td>Household work</td>
<td>144.87</td>
<td>96.44</td>
<td>173.42</td>
<td>111.72</td>
</tr>
<tr>
<td></td>
<td>(87.06)</td>
<td>(78.58)</td>
<td>(98.63)</td>
<td>(82.59)</td>
</tr>
<tr>
<td>Pur leisure</td>
<td>252.74</td>
<td>277.29</td>
<td>231.70</td>
<td>264.16</td>
</tr>
<tr>
<td></td>
<td>(95.10)</td>
<td>(122.34)</td>
<td>(89.17)</td>
<td>(106.57)</td>
</tr>
<tr>
<td>commuting</td>
<td>82.87</td>
<td>96.46</td>
<td>87.73</td>
<td>86.51</td>
</tr>
<tr>
<td></td>
<td>(42.47)</td>
<td>(60.84)</td>
<td>(51.71)</td>
<td>(52.22)</td>
</tr>
<tr>
<td>Observation</td>
<td>159</td>
<td>194</td>
<td>379</td>
<td>379</td>
</tr>
</tbody>
</table>

* in minutes per day. Standard deviation in parentheses.

to preferences and others to infrequency. Concerning time use, it is difficult to make this kind of assumptions.

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, like housework, leads to a reduction of zeros’ frequency: less than 1% of our observations. 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, 1973) and economies of scale, this paper aims to estimate economies of scale resulting from the publicness of the activities. Knowing how much time devoted to a specific domestic task, as house cleaning, a woman saves by living in a couple is not our focus, as it is household-specific. This paper aims to estimate welfare gains for broad activities.

The rationale to define aggregate activities results from this aim and econometric issues. First, we are interested in time gains regarding the main economic reason to form 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 & 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 to have given
working schedule. Finally, we distinguish sleeping and personal care because our
identification requires assignable activity (personal care) and adding-up restriction.

4.2 Empirical Implementation

4.2.1 Empirical Specification

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

$$U(t_i) = \prod_{j=1}^{K} (t_{ij} - \gamma_{ij})^{\rho_{ij}}$$

where $t_{ij}$ is the time devoted to the $j^{th}$ activity by individual $i$. The Stone-Geary
parameters, $\rho_{ij}$, are individual and good-specific (marginal budget shares). The in-
compressible levels of consumption of time-activity are denoted $\gamma_{ij}$. The sum of all
the proportions of the goods consumed must equal 1 ($\sum_{j=0}^{K} \rho_{ij} = 1$ and $0 < \rho_{ij} < 1$).

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 we let the individual welfare increase as soon as basic
needs are achieved which provides a micro-foundation to what Goodin et al. (2008)
denote "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 shape:

$$t_{ik} = \gamma_{ik} + \rho_{ik} (\tilde{T}_i - \sum_{j=1}^{K} \gamma_{ij}) + \varepsilon_{ik}$$ (9)

We parametrize $\rho_{ik}$ in the following way, including observed heterogeneity ($x$) in
income effects:

$$\rho_{ik} = \frac{e^{x_i \beta_i}}{1 + e^{x_i \beta_i}}$$

Data on single-individuals are used to estimate parameters $\gamma_{ik}$ and $\rho_{ik}$ 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 unob-
served heterogeneity $\varepsilon$, we obtain:

$$\begin{cases}
  t_{jf} = \frac{1}{1-(\alpha_f)^2} [\gamma_{jf} + \frac{\rho_{j}}{\pi_f} (\eta_f - \sum_{j=1}^{K} \gamma_{j}^{f} \pi_{j}) - \alpha_f (\gamma_{m}^{f} + \frac{\rho_{f}}{\pi_m} (\eta_m - \sum_{j=1}^{K} \gamma_{j}^{m} \pi_{j})]) + \varepsilon_{jf} \\
  t_{km} = \frac{1}{1-(\alpha_m)^2} [\gamma_{km} + \frac{\rho_{k}}{\pi_m} (\eta_m - \sum_{j=1}^{K} \gamma_{j}^{m} \pi_{j}) - \alpha_k (\gamma_{f}^{m} + \frac{\rho_{k}}{\pi_f} (\eta_f - \sum_{j=1}^{K} \gamma_{j}^{f} \pi_{j})))] + \varepsilon_{km}
\end{cases}$$ (10)

where $\eta_i = \tilde{F}_i(x, s)$ 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 $\eta_i$ as the time-use demands is homogeneous of degree zero. We assume that
\( \eta_i \) corresponds to \( \tilde{F}I_i \). Implicitly, it implies that we know the Pareto weight. The following estimation would be conditional to a given Pareto weight \( \mu \).

As we consider that gains from living together and the degree of publicness of time-activity could vary across household, we introduce heterogeneity in \( \alpha_k \) which depends on demographics (female and male age, age squared, qualification):

\[
\alpha^k_i = \frac{e^{x^{k,i} \nu_i}}{1 + e^{x^{k,i} \nu_i}}
\]

Equation (3) describes the structural form of the Lindahl prices which depend on the \( \alpha \) parameters as well as on the opportunity cost of non-market time \( \lambda_f \) and \( \lambda_m \). The latter are the derivatives of the indirect utility function \( V \) in respect to the spare time, \( \tilde{T} \). The indirect Stone-Geary utility function being:

\[
V_i(t_i) = \Pi_{l=1}^K K(\rho^l_i(\tilde{T}^l_i - \gamma^l_i))^{1-\sum_{l \neq j}^{K-1} \rho^l_i}.
\]

We derive with respect to spare time \( \tilde{T} \) and obtain:

\[
\lambda^i = (1 - \sum_{l \neq j}^{K-1} \rho^l_i)(\rho^l_i) (1 - \sum_{l \neq j}^{K-1} (\tilde{T}^l_i - \gamma^l_i))^{\sum_{l \neq j}^{K-1} \rho^l_i}
\]

The Lindhal prices can then be recovered. We then proceed to predictions of commodities \( z_i \) implicitly consumed by individuals living in a couple. Summing up these commodities give a private time equivalent\(^{10}\) for individuals who live in a couple denoted \( T^*_i = \sum_{k=1}^K z^k_i \). Obviously, these amounts depends on the level of economies of scales, for a given Pareto weight. Individual indifference scales and economies of scales can be computed using equations (7) and (8).

### 4.2.2 Estimation Strategy

The system of time-use demands (equations 9 and 10) is estimated by means of the Generalized Method of Moments (GMM) for singles and couples, assuming intra-group correlation, i.e. that the error terms are correlated across activities within households but uncorrelated across households.\(^{11}\)

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

As spare time depends on working hours, it could be endogenous. A natural instrument for working hours and, therefore for time resources, is wage rate since it is considered as 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 & Meghir (1991) note that the use of wage as instrument leads to difficulties. Beyond

\(^{10}\)It is worth noticing that there are valued at market prices \( p = 1 \).

\(^{11}\)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 are called for.
the selection problem, which refers to observability of wages only for workers, wage could be endogenous, due to measurement error, omitted variable or reverse causality. As the average hourly wage is computed as the quotient of weekly earnings by weekly working hours, any measurement error should introduce a spurious negative correlation between this instrument and the endogenous variable, namely labor supply (Mroz (1987)). Besides, household work and namely child care could be bought on the market, especially for individual with a higher leisure opportunity cost. Moreover, if the price of some activities like commuting is correlated with wages, elasticities estimation could be biased. Finally, wages are not exogenous since choices on the labor market are probably better characterized by labor contracts and choices of wage-hours package in the medium run.

Given those 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, a dummy variable for managerial responsibilities, for shift work and the local unemployment rate. Good instruments should be both relevant and valid: correlated with the endogenous regressors and orthogonal to the errors. To check the relevance and the validity of our instrumental strategy, several tests was performed. The first stage of instrumentation is observed, to (i) observe the correlation between instruments, the endogenous variables and the dependent ones for validity purposes, and (ii) confirm the endogeneity of the interest variable: the time resources. The Durbin-Wu-Hausman tests reject the exogeneity of time resources for each activities by gender. Second, instruments are correlated with the endogenous variable but uncorrelated with the dependent ones.

The F-statistic tests reject their weakness.\footnote{One rule of thumb is that an F-statistic below 10 is cause for weakness concern (Staiger & Stock (1997)). Here, the F-statistic is equal to 16.6 for female and 18.46 for male, and confirms the relevance of our instrument sets.} For single females, single males and couples we do not reject the over-identification test, 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 female 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 implicitly correspond to homogeneity and symmetry restrictions tests. Finally, we include two distribution factors in the full income estimations: the female to male ratio of wage and qualification.

### 4.3 Separability Tests

A simple test of weak separability consists of testing whether the time-demands $t^k_i$ 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 flexible second order polynomial of $\tilde{T}$, consumption $C$ and demographics $X$ (age, age squared, education, region and house ownership):

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

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

Table 2 – Separability Tests

<table>
<thead>
<tr>
<th></th>
<th>Single female</th>
<th>Single male</th>
<th>Female in couple</th>
<th>Male in couple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal care</td>
<td>-0.06</td>
<td>-0.09</td>
<td>-0.09**</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td>(-0.2)</td>
<td>(-0.56)</td>
<td>(-2.39)</td>
<td>-1.21</td>
</tr>
<tr>
<td>Housework</td>
<td>-0.54</td>
<td>0.22</td>
<td>-0.05</td>
<td>0.13**</td>
</tr>
<tr>
<td></td>
<td>(-1.15)</td>
<td>(0.95)</td>
<td>(-0.73)</td>
<td>(2.4)</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.92</td>
<td>-0.4</td>
<td>-0.07</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(1.83)</td>
<td>(-1.24)</td>
<td>(-1.15)</td>
<td>(-0.01)</td>
</tr>
<tr>
<td>Commuting</td>
<td>-0.005</td>
<td>-0.09</td>
<td>-0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(-0.02)</td>
<td>(-0.45)</td>
<td>(-0.33)</td>
<td>(-0.63)</td>
</tr>
</tbody>
</table>

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

Table 2 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 weakly income on time-demands we see that some of them are significant: the impact of personal care for female in couple and on housework for male in couple. We conclude that separability between consumption and daily time-allocation assumption is rejected for couples but not for singles. For couples, rejection of separability could be linked to non-separable utility function or non-separable time technology function.\(^{13}\) To take into account the rejection of separability we adopt a conditional approach without separability by adding the household consumption in covariates for the time-use technology function:

\[
\alpha_i^k = \alpha_i^k(x_i, C)
\]

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

### 4.4 Results

The first paragraph deals with estimation of single females and single males to recover the preference parameters. Table 3 shows the \( \rho \) parameters of the Stone-Geary welfare function.\(^{14}\) They are computed for the average non-labor income, age, age squared, education, house ownership, car availability and regional dummies. These coefficients correspond to the marginal share of each non-market activity in “discretionary time”. A significant proportion of discretionary-time is devoted to

\(^{13}\)Using our functional form (Stone-Geary utility function), we do not reject the separability assumption for singles.

\(^{14}\)The estimation results are presented in Appendix in Table 7.
leisure: 42% for female and 43% for male. Women seem to somehow voluntary choose to devote more time to housework: women spend 29% of 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 desutility of time spent working at household chores.

Table 3 – Preference Parameters

<table>
<thead>
<tr>
<th></th>
<th>Single Female</th>
<th>Single Male</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal Care</strong></td>
<td>0.079**</td>
<td>0.085***</td>
</tr>
<tr>
<td></td>
<td>(0.0323)</td>
<td>(0.0255)</td>
</tr>
<tr>
<td><strong>Housework</strong></td>
<td>0.285***</td>
<td>0.168***</td>
</tr>
<tr>
<td></td>
<td>(0.0467)</td>
<td>(0.0355)</td>
</tr>
<tr>
<td><strong>Leisure</strong></td>
<td>0.424***</td>
<td>0.431***</td>
</tr>
<tr>
<td></td>
<td>(0.0534)</td>
<td>(0.0504)</td>
</tr>
<tr>
<td><strong>Commuting</strong></td>
<td>0.02**</td>
<td>0.068**</td>
</tr>
<tr>
<td></td>
<td>(0.0092)</td>
<td>(0.0304)</td>
</tr>
<tr>
<td><strong>Sleeping</strong></td>
<td>0.192</td>
<td>0.248</td>
</tr>
</tbody>
</table>

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

Table 4 shows the estimated parameters of the time-use technology function \(\alpha\). As we include heterogeneity in the time-use technology parameters, results are estimated for the average sample. 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 couple life (household production), for the average sample.

Table 4 – Time-use technology function estimation and Lindahl Prices

<table>
<thead>
<tr>
<th></th>
<th>(\alpha)</th>
<th>(\pi_f)</th>
<th>(\pi_m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Housework</strong></td>
<td>0.08**</td>
<td>5.08***</td>
<td>5.37***</td>
</tr>
<tr>
<td></td>
<td>(0.039)</td>
<td>(0.33)</td>
<td>(0.77)</td>
</tr>
<tr>
<td><strong>Leisure</strong></td>
<td>0.22**</td>
<td>4.08***</td>
<td>4.61***</td>
</tr>
<tr>
<td></td>
<td>(0.088)</td>
<td>(0.733)</td>
<td>(0.773)</td>
</tr>
<tr>
<td><strong>Commuting</strong></td>
<td>0.08**</td>
<td>20.31***</td>
<td>27.92***</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(5.088)</td>
<td>(5.471)</td>
</tr>
</tbody>
</table>

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

Lindahl prices are also estimated in their reduced form. Table 4 presents the \(\pi\) estimates. They correspond to the price of private time equivalent within the household. Female Lindahl prices are lower than those of male for all activities. It

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15The estimation results are presented in Appendix in Table 8.
16It is worthy indicating that the reverse could be observed for some given household characteristics.
17The estimation results are presented in Appendix in Table 8.
suggests that on average women purchase private time equivalent cheaper than men do within the household. This could be related to the fact that the valuation of time decreases with the quantity of spare time (time minus time spent working on the labor market) which is on average higher for females. Taking into account economies of scale linked with couple life suggests that one hour devoted to housework or leisure purchased within the household is cheaper than their relative opportunity cost. In other words, time spent outside the labor market cost less than what the individual would earn by supplying this time on the labor market.

### Table 5 – Economies and Indifference Scales

<table>
<thead>
<tr>
<th></th>
<th>For 2 singles</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Economies of Scale (% of household spare time)</td>
<td>0.063</td>
<td>(0.074)</td>
</tr>
<tr>
<td>Economies of Scale (minutes)</td>
<td>135.60</td>
<td>(158.202)</td>
</tr>
<tr>
<td>Female Indifference Scale (% of household spare time)</td>
<td>0.54</td>
<td>(0.049)</td>
</tr>
<tr>
<td>Male Indifference Scale (% of household spare time)</td>
<td>0.52</td>
<td>(0.055)</td>
</tr>
</tbody>
</table>

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

The overall scale economy measure (Table 5) indicates that two singles living apart need 6.3% time more to achieve the same utility level as living in couple and maintaining the same preferences. A couple save 2h15 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 and more cheaply attain the same indifference curves: a single woman (men) requires 55% (52%) of joint time-resources to be as well as when she (he) lived in a couple.

### Table 6 – Economies of Scales by Activity and Household Member

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housework (% of time devoted to)</td>
<td>0.13</td>
<td>0.21</td>
</tr>
<tr>
<td>minutes</td>
<td>22.13</td>
<td>17.49</td>
</tr>
<tr>
<td>Leisure (% of time devoted to)</td>
<td>0.31</td>
<td>0.22</td>
</tr>
<tr>
<td>minutes</td>
<td>71.82</td>
<td>58.71</td>
</tr>
<tr>
<td>Commuting (% of time devoted to)</td>
<td>0.09</td>
<td>0.13</td>
</tr>
<tr>
<td>minutes</td>
<td>8.31</td>
<td>6.95</td>
</tr>
</tbody>
</table>

Computed at the average mean of the sample.

Then, economies of scale by activity and household member is presented in Table 6. Living in couple allows to save time. On average, a female wins 22 minutes of time devoted to housework, 72 min of leisure and 8 minutes of commuting per day. Living with his wife gives rise to economies of scale for 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 saving depends on the characteristics of the couple and some wife could for example loose time by living with her partner.

Interestingly, for a given Pareto weight and preferences of the average sample, women save more time that their partner by living in a couple. This could be ex-

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18 This is only true for the average sample of socio-demographics variables. For some couples, the inverse is observed.
explained by sample characteristics. Actually, first, women have on average more spare time than men. Second, single females spend much more time at housework than single males, this leads to 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. Preference and technology parameters imply that women save more time by forming a couple. Therefore, after couple dissolution, women require more compensation as 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, a full-time welfare analysis, gender inequality suggests that women benefits more than men to economies of scale generating by the couple formation.

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, contrary to 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 et al. (2012) to the case of time metric. We compute time equivalents for people living in couple and then compute the median of the distribution of times (spare time, i.e. 1440 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 is 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. It represents 3% of our sample, that is full-time worker living alone or with his partner without children or anybody else in the household.

5 Conclusion

This paper models and estimates equivalence scales and economies of scale in time use based on UK time use data. Following BCL, our equivalence scales overtake previous methodological shortfall in the related literature, comparing the same individual in different marital situations. While, two singles living apart require 2h15 more spare time to achieve the same utility level as when living in a couple, a single woman requires 55% of the couple time-resources to be as well-off as when she lived in a couple. We provide an individually-based definition of time-poverty for childless individuals. Having less than 15 hours spare time a day is considered as time poor. That these wastes or gains in time are individually defined but cannot be transferred. However, it allows comparing the welfare derived from individual time-uses. Well-being is mechanically higher if the individual has more control over his time, or if he has greater capacity to enjoy his time because he/she lives in a couple (ability to produce welfare, or “commodities” with time). This time metric has a main advantage : it does not require any reference to wage rates. So the valuation of time of two single individuals is taken as identical. This could be viewed as a proper ethical view. However, this advantage is also a drawback since we have no economic mean of providing an economic compensation to these time inequalities.

Gender differences in tastes are recognized to be a social construct. So one could 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 some observed characteristics, such as gender, is an ethical choice that we did not consider here.

Reminder that is an average for working and non-working day.
Our contribution remains dependent on a broad range of parametric and identifying assumptions. From policy perspectives since households with children are excluded and we focus on short-term choices, excluding labor supply and consumption choices. Moreover money is ruled-out and time remains a non-transferable good.

Despite these shortfalls, results brings important insights on how time-use and intra-household bargaining could affect welfare analysis. We show that the welfare derived from individual time-use activities tend to be increased by couple life on average. This is in line with what is usually found from consumption data. We also demonstrated that welfare interactions in time-use are high, even when considering ‘pure’ leisure categories. Interestingly, women tend to enjoy greater benefits than men by saving more time.

This counterintuitive result is due to implicit normative assumptions. When computing indifference scales, the social planner uses behavioral utility functions. This is an ethical recognition of the heterogeneity in needs between time categories and gender. As a consequence, housework needs for women are higher. This view could be questioned when computing poverty lines and compensation after couple dissolution (divorce, separation or death).

To be fully operational from a policy perspective, a more complete economic model should consider simultaneously monetary and time poverty, as well as potential substitution channels between consumption goods and time. A deep reflexion about implicit ethical assumptions undertaken in collective household models is also necessary. We could then move from a purely material redistributive aim to a broadly redistributive aim including the assessment of spare time.
Bibliographie


Appendix

A. Individual Lindahl Prices

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

\[
\begin{align*}
\max & \quad z_f, z_m, t_f, t_m \mu(\cdot)U_f(z_f) + U_m(z_m) \\
\text{st.} & \quad \sum_{k=1}^{K} t^k_i = \tilde{T}_i \\
& \quad z^k_f = t^k_f + \alpha^k t^k_m \\
& \quad z^k_m = t^k_m + \alpha^k t^k_f \\
& \quad t^k_i \geq 0, t^k_i \leq T \text{ for } i = f, m \text{ and } k = 1, \ldots, K
\end{align*}
\]

where \( \tilde{T}_i \) is spare time computed by subtracting 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 \( \sum t^k_i = \tilde{T}_i \Leftrightarrow \sum t^k_i = w_i \tilde{T}_i = FI \) where \( FI \) 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:

\[
\begin{align*}
\begin{cases}
  t^k_f = \frac{z^k_f - \alpha^k z^k_m}{1 - (\alpha^k)^2} \\
  t^k_m = \frac{z^k_m - \alpha^k z^k_f}{1 - (\alpha^k)^2}
\end{cases}, \text{ for } k = 1, \ldots, K
\end{align*}
\]

Substituting equation 12 the two time-budget constraints of program above leads to the new constraints and program:

\[
\begin{align*}
\max & \quad z_f, z_m \mu(\cdot)U_f(z_f) + U_m(z_m) \\
\text{st.} & \quad 1 - \sum_{k=1}^{K} \frac{z^k_f - \alpha^k z^k_m}{T_f(1-(\alpha^k)^2)} = 0 \\
& \quad 1 - \sum_{k=1}^{K} \frac{z^k_m - \alpha^k z^k_f}{T_m(1-(\alpha^k)^2)} = 0
\end{align*}
\]

We denote \( \lambda_f \) and \( \lambda_m \) the Lagrangian multipliers associated to the constraints in the program above.

Necessary conditions are:

\[
\begin{align*}
\begin{cases}
  \mu \frac{\partial u_f}{\partial z^k_f} = \frac{\lambda_f}{T_f(1-(\alpha^k)^2)} - \frac{\lambda_m \alpha^k}{T_m(1-(\alpha^k)^2)} \\
  \mu \frac{\partial u_m}{\partial z^k_m} = \frac{\lambda_f}{T_f(1-(\alpha^k)^2)} - \frac{\lambda_m \alpha^k}{T_m(1-(\alpha^k)^2)}
\end{cases}
\end{align*}
\]

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

\[
\begin{align*}
\max & \quad z_i \mu(\cdot)U_f(z_f) + U_m(z_m) \\
\text{st.} & \quad 1 - \sum_{k=1}^{K} \frac{z^k_i - \alpha^k z^k_i}{\eta_i^k} = 0 \\
& \quad \text{for } i = f, m
\end{align*}
\]

where \( \pi \) are the individual implicit evaluations of each commodity, \( \eta_i \) is the individual sharing rule.
Necessary conditions of dual program \((P^d)\) are:
\[
\begin{align*}
\mu \frac{\partial U_f}{\partial z_f} &= \lambda_f \frac{\pi_f}{\eta_f} \\
\mu \frac{\partial U_m}{\partial z_m} &= \lambda_m \frac{\pi_m}{\eta_m}
\end{align*}
\] (16)

Equalizing necessary conditions of \(P^c\) and \(P^d\) (equations 14 and 16) gives:
\[
\begin{align*}
\frac{\pi_f}{\eta_f} &= \frac{\lambda_f T_m - \lambda_m T_f \alpha_k}{\lambda_f T_f T_m [1 - (\alpha_k)^2]} \\
\frac{\pi_m}{\eta_m} &= \frac{\lambda_m T_f - \lambda_f T_m \alpha_k}{\lambda_m T_f T_m [1 - (\alpha_k)^2]}
\end{align*}
\] (17)

B. Estimation Results

Table 7 – Single Estimations

<table>
<thead>
<tr>
<th></th>
<th>Personal Care</th>
<th>Housework</th>
<th>Leisure</th>
<th>Commuting</th>
<th>Spare Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>0.082 (0.037)</td>
<td>0.200 (0.062)</td>
<td>0.488 (0.059)</td>
<td>0.010 (0.034)</td>
<td>1102.912 (12.353)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>0.000 (0.001)</td>
<td>0.002 (0.002)</td>
<td>-0.002 (0.002)</td>
<td>0.000 (0.002)</td>
<td>0.000 (0.001)</td>
</tr>
<tr>
<td><strong>Age squared</strong></td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>0.001 (0.001)</td>
<td>-0.001 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.001 (0.001)</td>
<td>0.001 (0.000)</td>
</tr>
<tr>
<td><strong>Region</strong></td>
<td>0.006 (0.004)</td>
<td>0.001 (0.007)</td>
<td>-0.016 (0.008)</td>
<td>0.005 (0.004)</td>
<td>0.005 (0.004)</td>
</tr>
<tr>
<td><strong>House Ownership</strong></td>
<td>0.002 (0.004)</td>
<td>-0.001 (0.005)</td>
<td>0.003 (0.006)</td>
<td>0.001 (0.003)</td>
<td>0.001 (0.003)</td>
</tr>
<tr>
<td><strong>Non-labor income</strong></td>
<td>0.555 (0.182)</td>
<td>0.36</td>
<td>0.37</td>
<td>0.33</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Manage</strong></td>
<td>-35.936 (15.766)</td>
<td>0.36</td>
<td>0.37</td>
<td>0.33</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Personal Care</th>
<th>Housework</th>
<th>Leisure</th>
<th>Commuting</th>
<th>Spare Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>0.077 (0.035)</td>
<td>0.134 (0.049)</td>
<td>0.414 (0.070)</td>
<td>0.042 (0.043)</td>
<td>1046.932 (13.556)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>-0.001 (0.001)</td>
<td>0.001 (0.001)</td>
<td>0.002 (0.003)</td>
<td>0.001 (0.001)</td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td><strong>Age squared</strong></td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>0.002 (0.001)</td>
<td>-0.001 (0.001)</td>
<td>-0.002 (0.002)</td>
<td>0.001 (0.001)</td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td><strong>Region</strong></td>
<td>0.007 (0.067)</td>
<td>-0.019 (0.008)</td>
<td>0.014 (0.011)</td>
<td>0.005 (0.006)</td>
<td>0.005 (0.006)</td>
</tr>
<tr>
<td><strong>House Ownership</strong></td>
<td>0.000 (0.004)</td>
<td>0.010 (0.006)</td>
<td>-0.014 (0.009)</td>
<td>0.010 (0.005)</td>
<td>0.010 (0.005)</td>
</tr>
<tr>
<td><strong>Non-labor income</strong></td>
<td>0.970 (0.243)</td>
<td>0.36</td>
<td>0.37</td>
<td>0.33</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>Manage</strong></td>
<td>-15.329 (5.818)</td>
<td>0.36</td>
<td>0.37</td>
<td>0.33</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Note that due to adding-up restriction, time devoted to sleeping is not estimated. Absolute standard errors are in parentheses.
### Table 8 – Couple Estimations

<table>
<thead>
<tr>
<th></th>
<th>$\alpha_2$</th>
<th>$\alpha_3$</th>
<th>$\alpha_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>-86.84 (36.321)</td>
<td>6.09 (2.647)</td>
<td>-327.78 (142.111)</td>
</tr>
<tr>
<td>Female Age</td>
<td>0.45 (0.194)</td>
<td>0.05 (0.0214)</td>
<td>28.94 (11.408)</td>
</tr>
<tr>
<td>Female Age squared</td>
<td>0.00 (0.001)</td>
<td>0.00 (0.000)</td>
<td>-0.63 (0.242)</td>
</tr>
<tr>
<td>Female Education</td>
<td>5.52 (2.33)</td>
<td>-0.47 (0.254)</td>
<td>1.24 (0.538)</td>
</tr>
<tr>
<td>Male Age</td>
<td>-0.10 (0.039)</td>
<td>0.00 (0.001)</td>
<td>-0.03 (0.012)</td>
</tr>
<tr>
<td>Male Age squared</td>
<td>2.11 (0.961)</td>
<td>0.08 (0.036)</td>
<td>-0.27 (0.116)</td>
</tr>
<tr>
<td>Male Education</td>
<td>0.24 (0.103)</td>
<td>-1.16 (-0.068)</td>
<td>1.24 (0.352)</td>
</tr>
<tr>
<td>Consumption</td>
<td>-0.04 (0.011)</td>
<td>0.00 (0.001)</td>
<td>-0.02 (0.009)</td>
</tr>
<tr>
<td><strong>Female Full Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>53.42 (11.545)</td>
<td>163.23 (29.237)</td>
<td></td>
</tr>
<tr>
<td>Education ratio</td>
<td>17.96 (3.914)</td>
<td>1.77 (0.769)</td>
<td></td>
</tr>
<tr>
<td>Wage ratio</td>
<td>0.41 (0.027)</td>
<td>-1.57 (0.096)</td>
<td></td>
</tr>
<tr>
<td>Partner’s Spare time</td>
<td>0.02 (0.010)</td>
<td>0.11 (0.054)</td>
<td></td>
</tr>
<tr>
<td>Non-labor income</td>
<td>0.04 (0.010)</td>
<td>-0.03 (0.011)</td>
<td></td>
</tr>
<tr>
<td><strong>Male Full Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>10.25 (1.460)</td>
<td>5.50 (0.928)</td>
<td>111.00 (17.752)</td>
</tr>
<tr>
<td>Female Age</td>
<td>-0.56 (0.079)</td>
<td>-0.39 (0.056)</td>
<td>-8.89 (1.220)</td>
</tr>
<tr>
<td>Female Age squared</td>
<td>0.01 (0.001)</td>
<td>0.01 (0.001)</td>
<td>0.17 (0.026)</td>
</tr>
<tr>
<td>Male Age</td>
<td>0.002 (0.001)</td>
<td>0.05 (0.018)</td>
<td>0.94 (0.154)</td>
</tr>
<tr>
<td>Male Age squared</td>
<td>-0.004 (0.001)</td>
<td>-0.01 (0.001)</td>
<td>-0.01 (0.002)</td>
</tr>
<tr>
<td>Male Education</td>
<td>0.40 (0.055)</td>
<td>0.28 (0.037)</td>
<td>2.89 (0.456)</td>
</tr>
<tr>
<td>Wage ratio</td>
<td>-0.89 (0.126)</td>
<td>-0.45 (0.045)</td>
<td>-6.78 (1.163)</td>
</tr>
</tbody>
</table>

Absolute standard errors are in parentheses.