Marital Matching, Economies of Scale and Intrahousehold Allocations*

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Abstract

We propose a novel structural method to empirically identify economies of scale in household consumption. We assume collective households with consumption technologies that define the public and private nature of expenditures through Barten scales. Our method recovers the technology by solely exploiting preference information revealed by households' consumption behavior. The method imposes no parametric structure on household decision processes, accounts for unobserved preference heterogeneity across individuals in different households, and requires only a single consumption observation per household. Our main identifying assumption is that the observed marital matchings are stable. We apply our method to data drawn from the US Panel Study of Income Dynamics (PSID), for which we assume that similar households (in terms of observed characteristics like age or region of residence) operate on the same marriage market and are characterized by a homogeneous consumption technology. This application shows that our method yields informative results on the nature of scale economies and intrahousehold allocation patterns. In addition, it allows us to define individual compensation schemes required to preserve the same consumption level in case of marriage dissolution or spousal death.

Keywords: marriage market, intrahousehold allocation, economies of scale, revealed preference, PSID.

*This paper is a tribute to Professor Anton Barten (1930-2016), who introduced us to structural demand econometrics at the KU Leuven.

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1 Introduction

A defining characteristic of multi-person households is that some goods are partly or completely publicly consumed, which gives rise to economies of scale. Think about housing, transportation or commodities produced by household work. The level of these scale economies will generally depend on both the household technology, which defines the (public versus private) nature of goods, and the individual preferences of household members, which define the allocation of household expenditures to the different goods. Understanding the nature of scale economies allows for addressing a variety of questions on interpersonal and interhousehold comparisons of well-being (see, e.g., Chiappori, 2016). For example, what are the consumption shares of husbands and wives in alternative household types? What is the income compensation a woman should receive to guarantee the same material well-being after her husband passed away? How should this compensation vary with the number of dependent children?

In the current paper, we propose a structural method to empirically identify economies of scale in household consumption. Our method recovers the consumption technology by solely exploiting preference information revealed by households' consumption behavior. We assume a household consumption model that has three main components. First, we follow Chiappori (1988, 1992) by assuming collective households that consist of individuals with heterogeneous preferences, who reach Pareto efficient intrahousehold allocations. Second, we adopt the framework of Browning, Chiappori and Lewbel (2013) and use Barten scales to define the public versus private nature of the goods consumed by the household (see also Barten, 1964, and Muellbauer, 1977). Finally, we exploit marriage market implications to identify households' scale economies. In this respect, our analysis fits within the economics perspective on marriage that was initiated by Becker (1973, 1974) and Becker, Landes and Michael (1977). These authors argue that individuals behave as rational utility maximizers when choosing their partners on the marriage market. We exploit this argument empirically and use the observed marital decisions to learn about the underlying individual preferences, household technologies and intrahousehold allocations, while explicitly accounting for economies of scale.

We extend the revealed preference methodology that was recently developed by Cherchye, Demuynck, De Rock and Vermeulen (2014). These authors derived the testable implications of stable marriage for observed household consumption patterns. They showed that these testable implications allow for identifying the within-household decision structure that underlies the observed household consumption behavior. An important difference between our study and the one of Cherchye, Demuynck, De Rock and Vermeulen is that these authors assumed the public or private nature of goods to be known a priori to the empirical analyst. By contrast, our method will define the nature of goods a posteriori by empirically identifying good-specific Barten scales under the maintained assumption of stable marriage. It will account for the possibility that some goods are partly privately and partly publicly consumed. The basic intuition behind our identification strategy is that higher economies of scale imply more gains from marriage, which leads to more competition in the marriage market. Conversely, lower economies of scale lead to less gains from marriage, which reduces the incentive to be married. By assuming marital stability for the observed households, we can define informative upper and lower bounds on good-specific Barten scales for different households. This effectively "set" identifies the level of household-specific economies of scale.

Our identification method has a number of additional features that are worth emphasizing. First, it does not impose any functional structure on the within-household decision process, which makes it intrinsically nonparametric. Next, the method allows for fully unobserved preference heterogeneity across individuals in different households, and requires only a single consumption observation per household. Interestingly, we will show that we do obtain informative results on households' scale economies even under these minimalistic priors. In their empirical analysis, Browning, Chiappori and Lewbel (2013) assumed that males and females in households have the same preferences as single males and females. We show that it is possible to obtain informative identification results without that assumption, by exploiting the testable implications of marriage stability. We believe that this is an attractive finding, as Browning, Chiappori and Lewbel's assumption of preference similarity is often regarded to be overly restrictive.[1]

We will apply our method to a cross-sectional household data set that is drawn from the 2013 wave of the US Panel Study of Income Dynamics (PSID). In this application, households allocate their full income (i.e. the sum of both spouses' maximum labor income and nonlabor income) to both spouses' leisure, two commodities produced through the spouses' household work and the consumption of a Hicksian aggregate good.[2] We build on the observation that household technologies are closely related to observable household characteristics. For example, it is often argued that the presence of children significantly impacts households' demand patterns (Browning, 1992). For our own sample of households, we find that households' consumption patterns vary substantially depending on the number of children, age, education level and region of residence (see Tables 15-18 in Appendix B).

By using our novel methodology, we can investigate how these diverging consumption patterns relate to households' economies of scale and intrahousehold allocations. For example, what is the effect of children on public consumption in households? Does it matter whether or not the husband has a college degree? Is the pattern of intrahousehold consumption sharing different according to the region of residence or the age category? Should we model household work as fully publicly consumed or also as partly private? To meaningfully analyze these questions, we will assume that

[1] Given the overidentification of the basic model of Browning, Chiappori and Lewbel (2013), there is room to parameterize preference changes due to marriage. Dunbar, Lewbel and Pendakur (2013) suggested an identification approach that no longer assumes that individuals in couples have the same preferences as singles. Their approach needs to assume either that preferences are similar across people for a given household type or, alternatively, that preferences are similar across household types for a given person. In our method, we account for fully unobserved preference heterogeneity across individuals in different households.

[2] We implicitly consider two types of household technologies. The focus of this paper is on household technologies *à la* Browning, Chiappori and Lewbel (2013), which are associated with economies of scale. The other type of household technologies are related to the transformation of time spent on domestic work to commodities consumed inside the household in a Becker (1965) fashion. Under appropriate assumptions, a spouse's time spent on domestic production can serve as the output of the home produced good by this spouse. We will come back to this in Section 2.

similar households (in terms of age, education, number of children and region of residence) operate on the same marriage market and are characterized by a homogeneous consumption technology. Our method then yields informative results on the nature of scale economies and intrahousehold allocation patterns for alternative household types. In turn, we can address the well-being questions that we mentioned above. As a specific illustration, we will compute individual compensation schemes required to preserve the same material well-being in case of marriage dissolution or spousal death.

The rest of this paper unfolds as follows. Section 2 introduces our notation and the structural components of our household consumption model. Section 3 formally defines our concept of stable marriage. Section 4 presents the testable implications of our model assumptions for observed household consumption patterns. Here, we will also indicate that these implications allow us to (set) identify households' economies of scale (i.e. Barten scales). Section 5 introduces the set-up of our empirical application. Section 6 presents our empirical findings regarding economies of scale for our sample of households, and Section 7 the associated results on intrahousehold allocation. Section 8 provides some concluding discussion.

2 Household Consumption

We study households that consist of two decision makers, a male m and a female f. As indicated above, our application will consider households that allocate their full income to spouses' leisure, household work and consumption of a Hicksian aggregate good. In what follows, we will provide more formal details on the household decision setting we have in mind. Subsequently, we will introduce our concept of consumption technology (with Barten scales). Finally, we will show how our set-up allows us to analyze households' economies of scale and intrahousehold allocation patterns.

Setting. We assume that each individual $i \in \{m, f\}$ spends his or her total time ($T \in \mathbb{R}_{++}$) on leisure ($l_i \in \mathbb{R}_+$), market work ($m_i \in \mathbb{R}_+$) and household work ($h_i \in \mathbb{R}_+$). The price of time for each individual is his or her wage ($w_i \in \mathbb{R}_{++}$) from market work. The time constraint for each individual is

$$T = l_i + m_i + h_i.$$

Let $q_{m,f} \in \mathbb{R}^K_+$ be a K-dimensional (column) vector denoting the observed aggregate consumption bundle for the pair (m, f). In our following empirical application, this vector will contain goods bought on the market (captured by a Hicksian aggregate good), as well as time spent on leisure and on household production by both individuals, which implies $K = 5$. Remark that each individual's time spent on household production actually represents an input and not an output that is consumed inside the household (see Becker, 1965). Under the assumption that each individual produces a different household good by means of an efficient one-input technology characterized by constant returns-to-scale, however, the individual's input value can serve as the output value.

Note that this implies specialization with respect to the production of household goods rather than specialization with respect to market work versus household work (see also Pollak and Wachter, 1975, and Pollak, 2013).

Consumption decisions are made under budget constraints that are defined by prices and incomes. For any pair (m, f), let $y_{m,f} \in \mathbb{R}_+$ denote the full potential income. Similarly, let $y_{m,\phi}$ and $y_{\phi,f} \in \mathbb{R}_+$ denote the full potential income of m and f when they are single. Further, let n_m and $n_f \in \mathbb{R}$ denote the nonlabor income of the two spouses. Specifically, we have:

$$y_{m,f} = w_m T + w_f T + n_m + n_f, \tag{1}$$
$$y_{m,\phi} = w_m T + n_m \text{ and}$$
$$y_{\phi,f} = w_f T + n_f.$$

Further, we let $p_{m,f} \in \mathbb{R}^K_{++}$ represent the (row) vector of prices faced by the pair (m, f), and $p_{m,\phi}, p_{\phi,f} \in \mathbb{R}^K_{++}$ the (row) vectors of prices faced by m and f when they are single. In our application, the price of the Hicksian market good will be normalized at unity. The prices for leisure and household production will equal the observed individual wages. We will assume that individuals' wages are unaffected by marital status or spousal characteristics (i.e. there is no marriage premium or penalty), which implies that they remain the same as in the current marriage when individuals become single or remarry some other potential partner.[3]

Consumption technology. We account for the possibility that some goods are partly or fully publicly consumed within the household. As indicated above, we operationalize this idea by using Barten scales. Specifically, we let A denote a $K \times K$ diagonal matrix that represents the degree of publicness for each individual good, with the k-th diagonal entry a_k representing the fraction of good k that is used for public consumption. If the k-th good is consumed entirely privately, then $a_k = 0$. Similarly, if the k-th good is consumed entirely publicly, then $a_k = 1$. In general, all entries of the technology matrix A are bounded between 0 and 1. The Barten scale is given as $(1 + a_k)$ for each good k; by construction, its value is situated between 1 (full private consumption) and 2 (full public consumption).[4]

If the pair (m, f) buys the bundle $q_{m,f} \in \mathbb{R}^K_+$, then $Aq_{m,f} \in \mathbb{R}^K_+$ is used for public consumption and $(I - A)q_{m,f} \in \mathbb{R}^K_+$ is used for private consumption. The private consumption bundle is shared between the partners. In particular, let $q^m_{m,f} \in \mathbb{R}^K_+$ and $q^f_{m,f} \in \mathbb{R}^K_+$ denote the spouses' private

[3] In principle, it is possible to relax this assumption of exogenous wages for the revealed preference method that we introduce below, along the lines suggested by Cherchye, Demuynck, De Rock and Vermeulen (2014). To facilitate our exposition, we abstract from this extension in our current analysis.

[4] As discussed in the Introduction, our use of Barten scales to model public versus private consumption follows Browning, Chiappori and Lewbel (2013). In their theoretical discussion, these authors also considered a more general setting in which households buy the bundle v and consume the bundle x such that $v = Bx + b$, where B is a nonsingular matrix and b is a vector. Our concept of Barten scales represents a special case of this general type of linear household technologies. See also Cherchye, De Rock, Surana and Vermeulen (2016) for a similar approach.

shares that satisfy the adding up constraint

$$q_{m,f}^{m} + q_{m,f}^{f} = (I - A)q_{m,f}.$$

For a given consumption bundle $q_{m,f}$, the household allocation is given as $(q_{m,f}^{m}, q_{m,f}^{f}, Aq_{m,f})$. We note that the consumption technology (represented by A) is assumed not to be match-specific. In our empirical application, however, we will allow for observable heterogeneity in the consumption technology by conditioning the value of A on observable household characteristics. In particular, we will assume that a household's consumption technology can vary with the number of children in the household, the region of residence, and the age and education level of the husband.[5] As we discuss in Sections 6 and 7, this assumption is sufficient to obtain informative empirical results when using cross-sectional household data (containing only a single observation per individual household). In principle, if we used a panel household data set (with a time-series of observations for each household), then we could account of unobserved heterogeneity of the household technologies as well. We will briefly return to this point in our concluding discussion in Section 8.

Economies of scale and intrahousehold allocation. Publicness of consumption leads to economies of scale, which represent gains from marriage. Following Browning, Chiappori and Lewbel (2013), we quantify economies of scale from living together as the ratio of the (sum of) the expenditures that the male and female would need as singles to buy their consumption bundles within marriage (i.e. public and private quantities evaluated at the observed market prices), divided by the actual (observed) outlay of the household. Formally, for each pair (m, f) we define the economies of scale measure

$$R_{m,f} = \frac{p_{m,f}(I + A)q_{m,f}}{y_{m,f}}. \tag{2}$$

By construction, we will have that $R_{m,f} \in [1, 2]$. If everything is consumed privately (i.e. $a_k = 0$ for all k), then $R_{m,f}$ will equal 1, which means that there are no economies of scale. At the other extreme, if all goods are consumed entirely publicly (i.e. $a_k = 1$ for all k), then $R_{m,f}$ equals 2 . If the household is characterized by both public and private consumption, then $R_{m,f}$ will be strictly between 1 and 2. Generally, our measure of scale economies quantifies a household's gains from sharing consumption. To take a specific example, let us assume that the measure equals 1.30 for some household. This means that the two individuals together would need 30% more income as singles to buy exactly the same aggregate bundle as in the household.[6]

[5] For our data set, we could also have conditioned the household technology on the age and education of the wife. We have chosen not to do so because the observed marriage matchings are largely positively assortative for these individual characteristics. For example, the sample correlation between the ages of husband and wife amounts to 95%, and the correlation between education levels is 71%.

[6] We remark that our measure of scale economies fixes the consumption level of the individuals at their within-marriage level when evaluating the cost of the counterfactual outside-marriage situation. This corresponds to a Slutsky-type income compensation (see Mas-Colell, Whinston and Green, 1995). An alternative is to consider a Hicksian-type compensation and to fix the individuals' utilities (instead of consumption bundles) at the within-marriage level. This alternative underlies the concept of indifference scales introduced by Browning, Chiappori and Lewbel (2013). As we briefly discuss in the concluding Section 8, such Hicksian-type compensation concepts can be

Two other useful measures are the male m's and female f's "relative individual cost of equivalent bundle" (RICEB).[7] These measures are defined as follows:

$$R_{m,f}^{m} = \frac{p_{m,\phi} q_{m,f}^{m} + p_{m,\phi} A q_{m,f}}{y_{m,f}} \text{ and} \quad (3)$$

$$R_{m,f}^{f} = \frac{p_{\phi,f} q_{m,f}^{f} + p_{\phi,f} A q_{m,f}}{y_{m,f}}. \quad (4)$$

The interpretation is similar to the scale economies measure $R_{m,f}$. Specifically, these RICEBs capture the fractions of household expenditures that males (females) would need as singles to achieve the same consumption level as under marriage at the new prices $p_{m,\phi}$ (resp. $p_{\phi,f}$). The RICEBs also describe the allocation of expenditures to the male and female in a given household. Given our particular setting, this allocation is defined by the household's economies of scale as well as the intrahousehold sharing pattern, which essentially reflects the individuals' bargaining positions. We will illustrate the importance of these two channels when interpreting the results for $R_{m,f}^{m}$ and $R_{m,f}^{f}$ in our empirical application.

The question remains what are the prices in $p_{m,\phi}$ and $p_{\phi,f}$ for the absent spouse's household work in case one becomes a single. In our application, we will assume that exactly the same public good produced by the absent spouse will be bought on the market. Given the earlier discussed production technology, this implies that we can use this spouse's wage as the price for the household work that serves as an input in the production process. Sometimes other options may be available, though. More detailed information on the time use of spouses, for example, would make it possible to use market prices for marketable commodities like formal child care, cleaning the house or gardening. Our current data set only contains an aggregate of the spouses' time spent on household work, which rules out such an approach.

3 Marital Stability

We study a marriage market that consists of a finite set of males M and a finite set of females F. The market is characterized by a matching function $\sigma : M \cup F \longrightarrow M \cup F \cup \{\phi\}$. This function tells us who is married to whom.[8] If the individual is married, then σ allocates to male m or female f a member of the opposite gender (i.e. $\sigma(m) = f$ and $\sigma(f) = m$). Alternatively, if the individual is single, then σ allocates nobody to him/her (i.e. $\sigma(m) = \phi$ and $\sigma(f) = \phi$). Obviously, m is matched to f if and only if f is matched to m, which means that the pair (m, f) is a married

operationalized when extending our framework towards a panel data setting (with a time-series of observations for each household). This remark directly carries over to the RICEB concepts that we define in (3) and (4). See also Chiappori and Meghir (2014) for an alternative individual welfare measure in a context with shared consumption.

[7] Browning, Chiappori and Weiss (2014, p. 64) define the relative cost of an equivalent bundle at the couple's level, which coincides with the economies of scale measure in equation (2). We define the relative cost at the individual level, which allows us to analyze the intrahousehold allocation of resources, as we will show in our empirical application.

[8] In our application, marriage stands for legal marriage as well as cohabitation.

couple. Formally, the function σ satisfies, for all $m \in M$ and $f \in F$,

$$\sigma(m) \in F \cup \{\phi\},$$
$$\sigma(f) \in M \cup \{\phi\} \text{ and}$$
$$\sigma(m) = f \in F \text{ iff } \sigma(f) = m \in M.$$

The current study will only consider married couples, i.e. $\sigma(m) \neq \phi$ for any $m \in M$ and $\sigma(f) \neq \phi$ for any $f \in F$ (which implies $|M| = |F|$). In principle, it is relatively easy to include singles in our framework (along the lines of Cherchye, Demuynck, De Rock and Vermeulen, 2014). However, our following application will show that our method gives informative results even if we do not use information on singles. Therefore, and also to simplify our exposition, we have chosen to only use couples' information in our analysis.

For a given matching function σ, the set $S = \{(q^m_{m,\sigma(m)}, q^{\sigma(m)}_{m,\sigma(m)}, Aq_{m,\sigma(m)})\}_{m\in M}$ represents the collection of household allocations defined over all matched pairs. In what follows, we will say that *a matching allocation S is stable if it is Pareto efficient, individually rational and has no blocking pairs*. Essentially, this means that the allocation S belongs to the core of all possible marriage allocations. To formally define our stability criteria, we will assume that every individual i is endowed with a utility function $u^i : \mathbb{R}^K_+ \longrightarrow \mathbb{R}_+$. These utility functions are individual-specific (i.e. fully unobserved heterogeneity) and egoistic in the sense that each individual is assumed to get utility only from the own private and public consumption. We further assume that the utility functions for all individuals are non-negative, increasing, continuous and concave. Finally, we make the technical assumption that $u^i(0, Aq) = 0$ (with Aq the amount of public consumption), i.e. each individual needs at least some private consumption (e.g. food) to achieve a positive utility level.

Pareto Efficiency. We assume that households make Pareto efficient decisions (following Chiappori, 1988, 1992). Pareto efficiency requires for every matched pair that the intrahousehold consumption allocation admits no Pareto improvement for the given budget constraint. In other words, there does not exist another feasible allocation that makes at least one spouse strictly better off without making the other spouse strictly worse off. Formally, the matching allocation S is Pareto efficient if, for any pair $(m, \sigma(m))$, there does not exist any other feasible allocation $(z^m_{m,\sigma(m)}, z^{\sigma(m)}_{m,\sigma(m)}, Az_{m,\sigma(m)})$, with $p_{m,\sigma(m)} z_{m,\sigma(m)} \leq y_{m,\sigma(m)}$, such that

$$u^m(z^m_{m,\sigma(m)}, Az_{m,\sigma(m)}) \geq u^m(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}) \text{ and}$$
$$u^{\sigma(m)}(z^{\sigma(m)}_{m,\sigma(m)}, Az_{m,\sigma(m)}) \geq u^{\sigma(m)}(q^{\sigma(m)}_{m,\sigma(m)}, Aq_{m,\sigma(m)}),$$

with at least one strict inequality.

Individual rationality. Using the definition of Gale and Shapley (1962), marital stability imposes that marriage matchings satisfy the conditions of individual rationality and no blocking pairs. Individual rationality requires that no individual wants to become single. That is, no individual can achieve a higher utility as single than under their current marriage. To formalize this criterion, let $U^m_{m,\phi}$ and $U^f_{\phi,f}$ denote that maximum utility that m and f can achieve when single (for prices $p_{m,\phi}$ and $p_{\phi,f}$ and incomes $y_{m,\phi}$ and $y_{\phi,f}$ respectively), i.e.

$$U^m_{m,\phi} = \max_q u^m(q^m, Aq) \text{ s.t. } p_{m,\phi} q \leq y_{m,\phi} \text{ and}$$
$$U^f_{\phi,f} = \max_q u^f(q^f, Aq) \text{ s.t. } p_{\phi,f} q \leq y_{\phi,f}.$$

Then, the matching allocation S is individually rational if, for every $m \in M$ and $f \in F$, we have

$$u^m(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}) \geq U^m_{m,\phi} \text{ and}$$
$$u^f(q^f_{\sigma(f),f}, Aq_{\sigma(f),f}) \geq U^f_{\phi,f}.$$

No blocking pairs. An unmatched pair (m, f) is said to be a blocking one if both m and f are better off, with at least one of them strictly better off, when matched together than under their current marriages. Formally, the matching allocation S has no blocking pairs if for any m and f such that $f \neq \sigma(m)$ there does not exist any feasible allocation $(q^m_{m,f}, q^f_{m,f}, Aq_{m,f})$, with $p_{m,f} q_{m,f} \leq y_{m,f}$, such that

$$u^m(q^m_{m,f}, Aq_{m,f}) \geq u^m(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}) \text{ and}$$
$$u^f(q^f_{m,f}, Aq_{m,f}) \geq u^f(q^f_{\sigma(f),f}, Aq_{\sigma(f),f}),$$

with at least one strict inequality.

4 Revealed Preference Conditions

In what follows, we first specify the type of data set that we will use in our following application, and we define what we mean by rationalizability by a stable matching. Subsequently, we will present our testable revealed preference conditions for a data set to be rationalizable. We will also show that these conditions can be relaxed by accounting for divorce costs (e.g. representing unobserved aspects of match quality). Our conditions are linear in unknowns, which makes them easy to use in practice. Finally, we will indicate how our conditions enable (set) identification of households' economies of scale and intrahousehold allocation patterns.

Rationalizability by a stable matching. We observe a data set $\mathcal{D}$ on males $m \in M$ and females $f \in F$ that contains the following information:

- the matching function σ,
- the consumption bundles $(q_{m,\sigma(m)})$ for all matched couples $(m, \sigma(m))$,

- the prices $p_{m,f}$ for all $m \in M \cup \{\phi\}$ and $f \in F \cup \{\phi\}$,
- total nonlabor incomes $n_{m,\sigma(m)}$ for all matched couples $(m, \sigma(m))$.

Obviously, to verify if a given marriage allocation is stable or not, the analyst needs to know who is married to whom (σ). Next, we observe the aggregate consumption demand ($q_{m,\sigma(m)}$) of the matched pairs $(m, \sigma(m))$ but not the associated intrahousehold allocation of this consumption. Similarly, we do not observe the aggregate consumption demand of the unmatched pairs (m, f) (with $f \neq \sigma(m)$). In our following conditions, we will treat the vector $q_{m,f}$ for $f \neq \sigma(m)$ as an unknown variable representing the potential consumption of (m, f). By contrast, we observe the prices for all decision situations, i.e. for observed marriages but also for unobserved singles and unobserved potential couples. We recall from Section 2 that the quantity vectors $q_{m,f}$ contain a Hicksian aggregate good and time spent on leisure as well as on household production and, correspondingly, the price vectors $p_{m,f}$ contain the price of the aggregate good (which we normalize at unity) and individual wages. Finally, for the observed/married couples $(m, \sigma(m))$ we use a consumption-based measure of total nonlabor income, i.e. nonlabor income equals full income minus reported consumption expenditures. Then, we treat individual nonlabor incomes as unknowns that are subject to the restriction that they must add up to the observed (consumption-based) total nonlabor income, i.e.[9]

$$n_{m,\sigma(m)} = n_m + n_{\sigma(m)},$$

and, for a given specification of the individual incomes n_m and $n_{\sigma(m)}$, we obtain the full incomes $y_{m,f}$, $y_{m,\phi}$ and $y_{\phi,f}$ as in (1).

We say that *the data set $\mathcal{D}$ is rationalizable by a stable matching if there exist nonlabor incomes n_m and n_f (defining $y_{m,f}$, $y_{m,\phi}$ and $y_{\phi,f}$), utility functions u^m and u^f, a $K \times K$ diagonal matrix A (with diagonal entries $0 \leq a_k \leq 1$) and individual quantities $q^m_{m,\sigma(m)}, q^{\sigma(m)}_{m,\sigma(m)} \in \mathbb{R}^K_+$, with*

$$q^m_{m,\sigma(m)} + q^{\sigma(m)}_{m,\sigma(m)} = (I - A)q_{m,\sigma(m)},$$

such that the matching allocation $\{(q^m_{m,\sigma(m)}, q^{\sigma(m)}_{m,\sigma(m)}, Aq_{m,\sigma(m)})\}_{m \in M}$ is stable. As discussed in the previous section, stability means that we can represent the observed consumption and marriage behavior as Pareto efficient, individually rational and without blocking pairs for some specification of the individual utilities and household technologies (i.e. Barten scales).

Testable implications. By extending the argument of Cherchye, Demuynck, De Rock and Vermeulen (2014) to our setting, we can define testable conditions for rationalizability by a stable matching that are intrinsically nonparametric. The conditions only use information that is con-

[9] As compared to the alternative that fixes the intrahousehold distribution of nonlabor income (e.g. 50% for each individual), this procedure to endogenously define the individual nonlabor incomes effectively puts minimal non-verifiable structure on these unobserved variables. However, to exclude unrealistic scenarios, in our application we will impose that individual nonlabor incomes after divorce must lie between 40% and 60% of the total nonlabor income under marriage. The same restriction was used by Cherchye, Demuynck, De Rock and Vermeulen (2014).

tained in the data set $\mathcal{D}$ and do not require any (non-verifiable) functional structure on the within-household decision process, which minimizes the risk of specification error. In addition, the conditions avoid any preference homogeneity assumption for individuals in different households. Moreover, they use only a single consumption observation per household, which makes them applicable to cross-sectional household data sets. The conditions are stated in the next result. (The proof of the result is given in Appendix A.)

Proposition 1 *The data set $\mathcal{D}$ is* rationalizable by a stable matching *only if there exists a $K \times K$ diagonal matrix A with diagonal entries $0 \leq a_k \leq 1$ (for all $k \in \{1, 2, \cdots, K\}$) and, for each matched pair $(m, \sigma(m))$,*

(a) nonlabor incomes n_m, $n_{\sigma(m)} \in \mathbb{R}$ with

$$n_{m,\sigma(m)} = n_m + n_{\sigma(m)}$$

(b) and individual quantities $q^m_{m,\sigma(m)}, q^{\sigma(m)}_{m,\sigma(m)} \in \mathbb{R}^K_+$ with

$$q^m_{m,\sigma(m)} + q^{\sigma(m)}_{m,\sigma(m)} = (I - A) q_{m,\sigma(m)},$$

that meet, for all males $m \in M$ and females $f \in F$,

(i) the individual rationality restrictions

$$(y_{m,\phi} =) \;\; w_m T + n_m \leq p_{m,\phi} q^m_{m,\sigma(m)} + p_{m,\phi} A q_{m,\sigma(m)} \;\; \text{and}$$
$$(y_{\phi,f} =) \;\; w_f T + n_f \leq p_{\phi,f} q^f_{\sigma(f),f} + p_{\phi,f} A q_{\sigma(f),f},$$

(ii) and the no blocking pair restrictions

$$(y_{m,f} =) \;\; w_m T + w_f T + n_m + n_f \leq p_{m,f} \left(q^m_{m,\sigma(m)} + q^f_{\sigma(f),f} \right) + p_{m,f} A \max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\}.$$

Interestingly, the testable implications in Proposition 1 are linear in the unknown technology matrix A, the nonlabor incomes n_m and $n_{\sigma(m)}$, and the individual quantities $q^m_{m,\sigma(m)}$ and $q^{\sigma(m)}_{m,\sigma(m)}$. This makes it easy to verify them in practice. The explanation of the different conditions is as follows. First, the proposition requires the construction of a technology matrix A of which the diagonal entries capture the degree of publicness in each consumption good, ranging from entirely private ($a_k = 0$) to entirely public ($a_k = 1$). Next, conditions (a) and (b) specify the adding up restrictions for matched couples that we discussed above, which pertain to the unknown individual nonlabor incomes and privately consumed quantities.

Further, conditions (i) and (ii) impose the individual rationality and no blocking pair restrictions that apply to a stable marriage allocation. They have intuitive revealed preference interpretations. More specifically, condition (i) requires, for each individual male and female, that the total income and prices faced under single status (i.e. $y_{m,\phi}$ and $p_{m,\phi}$ for male m and $p_{\phi,f}$ and $y_{\phi,f}$ for female f) cannot afford a bundle that is strictly more expensive than the one consumed under the current marriage (i.e. $\left(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}\right)$ for m and $\left(q^f_{\sigma(f),f}, Aq_{\sigma(f),f}\right)$ for f). Indeed, if this condition were not satisfied for some individual, then he or she would be strictly better off as a single. Similarly, condition (ii) imposes, for each potentially blocking (i.e. currently unmatched) pair (m, f), that the total income $(y_{m,f})$ and prices $(p_{m,f})$ cannot afford a bundle that is strictly more expensive than the sum of the individuals' private bundles (i.e. $q^m_{m,\sigma(m)} + q^f_{\sigma(f),f}$) and the public bundle that is composed of the highest quantities consumed in the current marriages (which is defined as $A\max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\}$).[10] Intuitively, if this condition is not met, then man m and woman f can allocate their joint income so that they are both better off (with at least one strictly better off) than with their current partners.

Divorce Costs. So far, we have assumed that marriage decisions are only driven by material payoffs captured by the individual consumption bundles $\left(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}\right)$ for males m and $\left(q^f_{\sigma(f),f}, Aq_{\sigma(f),f}\right)$ for females f. Implicitly, we assumed that there are no gains from marriage originating from unobserved match quality (such as love or companionship). We have also abstracted from frictions on the marriage market and costs associated with marriage formation and dissolution.

In our empirical application, we will follow Cherchye, Demuynck, De Rock and Vermeulen (2014) and include the possibility that these different aspects may give rise to costs of divorce, which makes that the observed consumption behavior (captured by the observed data set $\mathcal{D}$) may violate the strict rationality requirements in Proposition 1. In particular, we make use of "stability indices" to weaken these strict constraints. Intuitively, these indices represent income losses associated with the different exit options from marriage (i.e. becoming single or remarrying a different partner). We represent these post-divorce losses as percentages of potential labor incomes.[11]

Formally, starting from our characterization in Proposition 1, we include a stability index in each restriction of individual rationality (i.e. $s^{IR}_{m,\phi}$ for male m and $s^{IR}_{\phi,f}$ for female f) and no blocking pair (i.e. $s^{NBP}_{m,f}$ for the pair (m, f)). Specifically, we replace the inequalities in condition (i) of Proposition 1 by

$$s^{IR}_{m,\phi} \times w_m T + n_m \leq p_{m,\phi} q^m_{m,\sigma(m)} + p_{m,\phi} A q_{m,\sigma(m)} \text{ and} \\ s^{IR}_{\phi,f} \times w_f T + n_f \leq p_{\phi,f} q^f_{\sigma(f),f} + p_{\phi,f} A q_{\sigma(f),f}, \quad (5)$$

and the inequality in condition (ii) of Proposition 1 by

$$s^{NBP}_{m,f} \times (w_m T + w_f T) + n_m + n_f \leq p_{m,f} q^m_{m,\sigma(m)} + p_{m,f} q^f_{\sigma(f),f} + p_{m,f} A \max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\}. \quad (6)$$

[10] The expression $\max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\}$ represents the element-by-element maximum, i.e. $q = \max\{q^1, q^2\}$ indicates $q_k = \max\{q^1_k, q^2_k\}$ for all goods k.

[11] We consider adjustment in labor incomes because nonlabor incomes are unknown variables in our conditions in Proposition 1. By only considering post-divorce adjustments of labor incomes, we preserve linearity in unknowns when treating the stability indices as unknown variables. This enables us to use linear programming to compute these indices (see our following discussion of (7)).

We also add the restriction $0 \leq s^{IR}_{m,\phi}, s^{IR}_{\phi,f}, s^{NBP}_{m,f} \leq 1$. Generally, a lower stability index corresponds to a greater income loss associated with a particular option to exit marriage.

Then, we can compute

$$\max \sum_{m \in M} s^{IR}_{m,\phi} + \sum_{f \in F} s^{IR}_{\phi,f} + \sum_{m \in M, f \in F} s^{NBP}_{m,f}. \tag{7}$$

subject to the feasibility conditions for the technology matrix A, the restrictions (a) and (b) in Proposition 1, and the linear constraints (5) and (6). We can solve (7) by simple linear programming. This will compute a different stability index for every individual rationality constraint (i.e. $s^{IR}_{m,\phi}$ and $s^{IR}_{\phi,f}$) and no blocking pair constraint (i.e. $s^{NBP}_{m,f}$). Intuitively, for each different exit option, it defines a minimal divorce cost that is needed to rationalize the observed marriage behavior by a stable matching allocation. These post-divorce income losses equal $(1 - s^{IR}_{m,\phi}) \times 100$ and $(1 - s^{IR}_{\phi,f}) \times 100$ for each exit option to become single and, similarly, $(1 - s^{NBP}_{m,f}) \times 100$ for every remarriage option.

Set identification. In our application, we will use the computed values of $s^{IR}_{m,\phi}$, $s^{IR}_{\phi,f}$ and $s^{NBP}_{m,f}$ to rescale the original potential labor incomes ($w_m T$, $w_f T$ and $w_m T + w_f T$), which will define an adjusted data set that is rationalizable by a stable matching. For this new data set, we can address alternative identification questions by starting from our rationalizability conditions.

In the following sections, we will specifically focus on the scale economies measure $R_{m,f}$ in (2) and the associated RICEB measures $R^m_{m,f}$ in (3) and $R^f_{m,f}$ in (4). Attractively, these measures $R_{m,f}$, $R^m_{m,f}$ and $R^f_{m,f}$ are also linear in the unknown matrix A and individual quantities $q^m_{m,\sigma(m)}$ and $q^{\sigma(m)}_{m,\sigma(m)}$. As a result, we can define upper/lower bounds on these measures by maximizing/minimizing these linear functions subject to our linear rationalizability restrictions. This "set" identifies the households' economies of scale and intrahousehold allocation patterns, through linear programming. This set identification essentially only exploits marital stability as identifying assumption, without any further parametric structure for intrahousehold decision processes or homogeneity assumptions regarding individual preferences.

5 Empirical Application: Set-up

We consider households that spend their full income (i.e. potential labor income and nonlabor income) on a Hicksian aggregate market good, time for household production and time for leisure. Our data set includes information on individuals' time use for household work and for leisure. In our model, we only associate (potential) economies of scale with consumption goods that have market substitutes; these scale economies can effectively be compensated in case of spousal death or marriage dissolution. As an implication, we allow the Hicksian market good and time spent on household production to be characterized by a public component, while time spent on leisure is modeled as purely private.

Data. We use household data drawn from the 2013 wave of the Panel Study of Income Dynamics (PSID). The PSID data collection began in 1968 with a nationally representative sample of over 18,000 individuals living in 5,000 families in the United States. The data set contains a rich set of information on households' labor supply, income, wealth, health and other sociodemographic variables. From 1999 onwards, the panel data is supplemented by detailed information on households' consumption expenditures. The 2013 wave includes data on 9063 households.

In our empirical analysis, we focus on couples with or without children and no other family member living in the household. Because we need wage information, we only consider households in which both spouses work at least 10 hours per week on the labor market. After removing observations with missing information (e.g. on time use) and outliers, we end up with a sample with 1321 households.

Table 1 provides summary information on the households that we consider. Wages are hourly wage rates, and market work, household work and leisure are expressed in hours per week. We compute leisure quantities by assuming that each individual needs 8 hours per day for sleep and personal care (i.e. leisure = (24-8)*7 - market work - household work). Consumption stands for dollars per week spent on market goods. We compute the quantity of this good as the sum of household expenditures on food, housing, transport, education, childcare, health care, clothing and recreation.[12] Appendix B gives additional details on our variable definitions and household data (see Tables 15-18).

	Mean	Std. Dev.	Min	Max
male wage	29.76	19.56	2.75	116.62
female wage	23.51	14.72	2.50	85.85
market work male	44.96	10.81	10.00	100.00
market work female	37.88	11.33	10.00	96.00
household work male	7.47	6.28	0.00	50.00
household work female	13.31	9.63	0.00	77.00
leisure male	59.57	12.16	0.00	99.00
leisure female	60.82	12.43	0.00	98.00
male age	40.79	11.85	20.00	82.00
female age	39.01	11.61	19.00	77.00
children	1.14	1.21	0.00	7.00
consumption	1198.90	545.45	250.12	5375.00

Table 1: sample summary statistics

Marriage markets. As indicated above, we let household technologies vary with observable household characteristics (i.e. age, education, number of children and region of residence). We use the same observable characteristics to define households' marriage markets. As an implication, while

[12] We do not observe intraregional price variation for food, house, transport, education, childcare, health care, clothing and recreation in our original PSID dataset. As we will explain further on, we will consider testable implications of our household consumption model for marriage markets defined at the regional level. Therefore, there is no value added of disaggregating our Hicksian market good for our empirical analysis.

our analysis accounts for fully (unobservably) heterogeneous individual preferences (as explained before), we do consider that all potential couples on the same marriage market are characterized by a homogeneous consumption technology (defining the public versus private nature of goods). Thus, we specifically focus on marriage matchings on the basis of individuals' preferences for the public and private goods that are consumed within the households, and we build on this premise to learn about the underlying household technology from the observed marriage matchings.

Evidently, in real life individuals may well account for remarriage possibilities that are characterized by different technologies (for different household characteristics). In addition, they may also consider repartnering with other individuals who are currently single. Including information on these additional repartnering options would increase the number of potentially blocking pairs, and this can only improve our identification analysis.[13] From this perspective, our following empirical analysis adopts a "conservative" approach and only uses largely uncontroversial assumptions on individuals' remarriage options. We will show that even this minimalistic set-up leads to insightful empirical conclusions.

Concretely, we have partitioned our sample of households in 160 different marriage markets. The partitioning is based on a categorical variable for the age group of the husband (i.e. below 30 years, between 31 and 40 years, between 41 and 50 years, between 51 and 60 years or at least 61 years), a dummy variable indicating whether the husband has a college degree or not, a categorical variable for the number of children that live in the household (i.e. 0, 1, 2 or at least 3 children), and a categorical variable indicating the region of residence (i.e. Northeast, North Central, South or West). We observe no households for 32 of the 160 marriage markets. We applied our revealed preference methodology outlined in Section 4 to each of the remaining 128 markets. Marriage market sizes range from 1 to 38 household observations, with an average of 10 observations per market. See Tables 11-14 in Appendix B for more detailed information.[14]

Divorce costs. When checking the strict rationalizability conditions in Proposition 1, we found consistency for 68 out of the 128 marriage markets. For the remaining 60 markets, we solved (7) to compute the divorce costs that we need to rationalize the observed consumption and marriage behavior. As explained in Section 4, for each different exit option (i.e. becoming single or remarrying) this computes a minimal divorce cost that makes the observed data set consistent with the sharp restrictions in Proposition 1. These divorce costs can be interpreted in terms of unobserved aspects that drive (re)marriage decisions, such as match quality and frictions on the marriage markets.

Table 2 summarizes our results. The second and third column show the divorce costs pertaining to the individual rationality conditions of the males and the females in our sample. The fourth and fifth column relate to the no blocking pair restrictions. For a matched pair $(m, \sigma(m))$, Average

[13] Technically, including additional blocking pair constraints will lead to smaller feasible sets characterized by the rationalizability constraints (like condition (5) in Proposition 1). In turn, this will lead to sharper upper and lower bounds (i.e. tighter set identification).

[14] From Appendix B, we observe that there are 15 marriage markets with a single household observation. In these cases, the identification of household technologies is completely driven by the individual rationality restrictions in Proposition 1.

cost stands for the average divorce cost defined over all remarriage options taken up in our analysis (i.e. the mean of the values $(1 - s^{NBP}_{m,f'}) \times 100$ and $(1 - s^{NBP}_{m',\sigma(m)}) \times 100$ over all f' and m'), and Maximum cost for the highest divorce cost necessary to neutralize all possible remarriages (i.e. the maximum of the values $(1-s^{NBP}_{m,f'}) \times 100$ and $(1-s^{NBP}_{m',\sigma(m)}) \times 100$ over all f' and m'). Intuitively, the Average divorce cost pertains to the "average" remarriage option (in terms of material consumption possibilities), while the Maximum divorce cost is defined by the "most attractive" remarriage option.

We observe that about 88% of the males and 98% of the females in our sample satisfy the strict individual rationality conditions (i.e. the associated divorce costs are zero). Next, the mean divorce costs for these individual rationality restrictions equal no more than 0.34% for the males and 0.05% for the females. These results suggest that very few males and even fewer females have an incentive to become single. Given our particular set-up, a natural explanation is that the observed marriages are characterized by economies of scale, which is what we investigate in the following Section 6. However, some individuals need a relatively high divorce cost to rationalize their behavior. For instance, the maximum values in Table 2 reveal that individual rationality requires a cost of becoming single that amounts to no less than 14.74% for at least one male and 10.47% for at least one female.

Further, we see that almost 70% of the married couples in our sample are stable in terms of the no blocking pair restrictions. Similar to before, the mean values for the Average and Maximum costs are fairly low (i.e. 0.05% for the Average divorce cost and 1.01% for the Maximum divorce cost). Once more, the maximum values (i.e. 3.82% for the males and 11.96% for the females) show that we need a rather significant divorce cost to rationalize the marriage behavior of some couples.

	Individual Rationality		No Blocking Pairs	
	Male	Female	Average	Maximum
fraction of zeros	87.81	98.49	69.49	69.49
mean	0.34	0.05	0.05	1.01
std. dev.	1.35	0.54	0.22	2.21
min	0.00	0.00	0.00	0.00
1st quartile	0.00	0.00	0.00	0.00
median	0.00	0.00	0.00	0.00
3rd quartile	0.00	0.00	0.02	0.78
max	14.74	10.47	3.82	11.96

Table 2: divorce costs as a fraction of post-divorce income (in %)

6 Economies of scale

By using the divorce costs summarized in Table 2, we can construct a new data set that is rationalizable by a stable matching. In turn, this allows us to set identify the decision structure underlying the observed stable marriage behavior. We begin by considering the upper and lower bound estimates for the scale economies measure $R_{m,f}$ in (2). In doing so, we will also consider the associated good-specific Barten scales (i.e. the diagonal entries of the household technology matrix A). In our application, these Barten scales capture the degree of publicness of spouses' household work and couples' consumption of market goods. We will end this section by conducting a regression analysis that relates our scale economies estimates to observable household characteristics.

Identification results. As a first step, we compare our estimated upper and lower bounds with so-called "naive" bounds. These naive bounds do not make use of the (theoretical) restrictions associated with a stable matching allocation, and are defined as follows. The lower bound corresponds to a situation in which A equals the zero matrix, which means that there is no public consumption at all. By contrast, the naive upper bound complies with the other extreme scenario in which spouses' household work and market goods are entirely publicly consumed, which corresponds to a value of unity for the diagonal elements of the matrix A. Note that the private consumption of leisure implies that this upper bound will in general be different from two, which would be the upper bound in case all commodities are purely publicly consumed. In what follows, we call the bounds that we obtain by our methodology "stable" bounds, as they correspond to a stable matching allocation on the marriage market. Comparing these stable bounds with the naive bounds will provide insight into the identifying power of the stable marriage restrictions.

The results of this comparison are summarized in Table 3. Columns 2-4 describe the bounds for $R_{m,f}$ that we estimate by our method, and columns 5-7 report on the associated naive bounds. We also give summary statistics on the percentage point differences between the (stable and naive) upper and lower bounds (see the "Difference" columns); these differences indicate the tightness of the bounds for the different households in our sample. To interpret these results, we recall that leisure is assumed to be fully privately consumed. However, as extensively discussed above, we do not impose any assumption regarding the public or private nature of the remaining expenditure categories (i.e. household work and market goods). Even under our minimalistic set-up, our identification method does yield informative results. Specifically, the average lower bound on $R_{m,f}$ equals 1.06 while the upper bound amounts to 1.18, yielding a difference of only 12 percentage points. Importantly, these stable bounds are substantially tighter than the naive bounds. The naive lower bound is 1.00 by construction and the upper bound equals 1.36 on average, which implies a difference of no less than 36 percentage points. Moreover, for 50% of the observed households we obtain a difference of less than 5 percentage points, which is substantially tighter than for the naive bounds.

As a following exercise, Table 4 reports on our estimates of the diagonal entries a_k (for each good k) of the technology matrix A that underlies the scale economies results in Table 3. For the spouses' household work and the Hicksian market good, the "Min" columns 2, 5 and 8 correspond to the lower stable bounds in Table 3, the "Max" columns 3, 6 and 9 to the upper stable bounds, and the "Avg" columns 4, 7 and 10 to the average of the Min and Max estimates. We note that the associated "naive" estimates of the a_k-entries (underlying the naive bounds in Table 3) trivially equal 0 for the minimum scenario and 1 for the maximum scenario, by construction.

	Stable			Naive		
	Min	Max	Difference	Min	Max	Difference
mean	1.06	1.18	0.13	1.00	1.36	0.36
std. dev.	0.06	0.12	0.15	0.00	0.11	0.11
minimum	1.00	1.00	0.00	1.00	1.10	0.10
1st quartile	1.00	1.09	0.00	1.00	1.29	0.29
median	1.04	1.15	0.05	1.00	1.35	0.35
3rd quartile	1.10	1.25	0.23	1.00	1.43	0.43
maximum	1.35	1.67	0.67	1.00	1.79	0.79

Table 3: economies of scale

Table 4 again shows the informative nature of the bounds that we obtain. On average, there seems to be some difference in publicness of household work by females or by males: the respective lower bounds equal 0.25 and 0.15, and the associated upper bounds amount to 0.52 and 0.40. Interestingly, our results do reveal quite some variation across households: in some households all household work is privately consumed (i.e. the minimum value for the upper bound on a_k equals 0), while in other households the consumption is fully public (i.e. the maximum value for the lower bound on a_k equals 1).

Next, we find that the average a_k-estimate for the Hicksian market good is situated between 0.14 (lower bound) and 0.47 (upper bound), which implies that the Barten scale for market goods (defined as $1 + a_k$) is situated between 1.14 and 1.47. These estimates are reasonably close to other estimates that have been reported in the literature (for different household samples, without leisure and using a parametric methodology). For example, Browning, Chiappori and Lewbel (2013) measure scale economies for Canadian households that correspond to an average Barten scale of 1.52 for market goods, and Cherchye, De Rock and Vermeulen (2012) compute an average Barten scale that equals 1.38 for the market consumption of Dutch elderly couples. Once more, we observe quite some heterogeneity in the a_k-estimates across households (ranging from a minimum value for the upper bound of 0 to a maximum value for the lower bound of 0.93).

	House work by Female			House work by Male			Market Good		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
mean	0.25	0.52	0.38	0.15	0.40	0.28	0.14	0.47	0.31
std. dev.	0.31	0.39	0.28	0.26	0.41	0.26	0.18	0.30	0.16
minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1st quartile	0.00	0.16	0.16	0.00	0.00	0.00	0.00	0.24	0.18
median	0.12	0.47	0.42	0.00	0.30	0.28	0.05	0.41	0.31
3rd quartile	0.44	1.00	0.50	0.27	0.92	0.50	0.29	0.69	0.43
maximum	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	0.94

Table 4: degree of publicness

Interhousehold heterogeneity. The results in Tables 3 and 4 show the potential of our identification method to obtain informative results, even if we make minimal assumptions regarding the data at hand. Moreover, our findings reveal quite some interhousehold heterogeneity in the patterns of scale economies. We investigate this further by relating the estimates summarized in Table 3 to observable household characteristics. This should provide additional insight into which household types are particularly characterized by higher or lower economies of scale. Specifically, we conduct two regression exercises: our first exercise uses interval regression and explicitly takes the (difference between) lower and upper bounds into account, while our second exercise is a simple OLS regression that uses the average of the lower and upper bounds as the dependent variable.

Our findings are summarized in Table 5. Interestingly, the results of the two regressions are very similar, which we believe supports the robustness of our conclusions. We also observe that quite many observable household characteristics correlate significantly with our scale economies estimates.[15]

Generally, it appears that poorer households consume more publicly than richer households with similar characteristics. But the intrahousehold distribution of the labor income (measured by the wage ratio) does not seem to relate to a household's scale economies. Next, we learn that couples with dependent children are generally characterized by higher economies of scale than couples without children. This reveals that the presence of children boosts the publicness of household work and household consumption, which conforms to our intuition.

Further, we find that the publicness of household consumption varies with the age structure, all else equal. Lastly, we find evidence that households located in the North Central and South regions experience systematically less scale economies than households in the Northeast region. One possible explanation is that residing in the Northeast is associated with a higher cost-of-living because of more expensive real estate, and this gives rise to more public expenditures.

7 Intrahousehold allocation

As explained in Section 2, we can also use our methodology to calculate bounds on the male and female "relative individual costs of equivalent bundles" (RICEBs) $R^m_{m,f}$ and $R^f_{m,f}$ (see (3) and (4)). Basically, these individual RICEBs quantify who consumes what relative to the household's full income. In what follows, we will investigate these RICEBs in more detail, and this will provide specific insights into intrahousehold allocation patterns. We will also use the results of this investigation to compute individual compensation schemes needed to preserve the same consumption level in case of marriage dissolution or spousal death. More generally, this illustrates the usefulness of our methodology to address the well-being questions that we listed in the Introduction.

RICEBs. Similar to before, we start by comparing the "stable" RICEB bounds, which we obtain through our identification method, with "naive" bounds. For a given individual, the naive lower bound equals the fraction of the budget share of the individual's leisure consumption (which is

[15] We also ran these regressions with the size of the marriage market added as an independent variable. The results obtained are qualitatively and quantitatively very similar to those reported here. The same remark applies to our regression results in Table 8.

	Interval	OLS
$\log(w_f/w_m)$	0.00334	0.000755
	(0.00204)	(0.00215)
log(total income)	-0.0253***	-0.0365***
	(0.00410)	(0.00404)
husband has a college degree	0.00822	-0.00668
	(0.00544)	(0.00500)
one child	0.0687***	0.0611***
	(0.00603)	(0.00446)
two children	0.0674***	0.0613***
	(0.00536)	(0.00471)
more than two children	0.0589***	0.0706***
	(0.00674)	(0.00595)
$31 \leq age_m \leq 40$	-0.0129**	-0.00821*
	(0.00559)	(0.00457)
$41 \leq age_m \leq 50$	-0.0198***	-0.00307
	(0.00671)	(0.00548)
$51 \leq age_m \leq 60$	0.00577	0.0161***
	(0.00525)	(0.00564)
$61 \leq age_m$	-0.0145***	0.00260
	(0.00477)	(0.00573)
North Central	0.00637	-0.0111**
	(0.00491)	(0.00474)
South	-0.00574	-0.0209***
	(0.00441)	(0.00451)
West	-0.00635	-0.00293
	(0.00499)	(0.00513)
$age_m - age_f$	-0.000344	-0.000726*
	(0.000406)	(0.000410)
$degree_m - degree_f$	0.00244	-0.00384
	(0.00395)	(0.00415)
constant	1.286***	1.408***
	(0.0340)	(0.0333)
observations	1,138	1,138
R-squared		0.309

robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: economies of scale and household characteristics

assignable and private), while the naive upper bound equals this lower bound plus the budget share of the household's non-leisure consumption (which is non-assignable). The results of this exercise are summarized in Table 6. Like before, we also report on the percentage point differences between the (stable and naive) upper and lower bounds (see the "Diff" columns).

Once more, we conclude that our method has substantial identifying power. The stable bounds are considerably tighter than the naive bounds, with the average difference between upper and lower bounds narrowing down from 36 percentage points (for the naive bounds) to no more than 9 to 11 percentage points (for the stable bounds). The stable bounds are also informatively tight. For example, we learn that, on average, males seem to have more control over household expenditures than females: the average male RICEB is situated between 55% and 64%, while the average female RICEB is only between 47% and 58%. Like before, however, there is quite some heterogeneity between households: lower bounds for females (resp. males) range from 2% to 95% (resp. 5% to 99%) and upper bounds from 5% to 99% (resp. 16% to 99%).

	Stable						Naive					
	Female			Male			Female			Male		
	Min	Max	Diff	Min	Max	Diff	Min	Max	Diff	Min	Max	Diff
mean	0.47	0.58	0.11	0.55	0.64	0.09	0.29	0.65	0.36	0.35	0.71	0.36
std. dev.	0.18	0.17	0.10	0.18	0.16	0.08	0.12	0.13	0.11	0.13	0.12	0.11
minimum	0.02	0.05	0.00	0.05	0.16	0.00	0.00	0.23	0.10	0.00	0.19	0.10
1st quartile	0.34	0.47	0.03	0.44	0.54	0.03	0.21	0.57	0.29	0.26	0.64	0.29
median	0.47	0.60	0.08	0.54	0.65	0.07	0.29	0.66	0.35	0.34	0.71	0.35
3rd quartile	0.59	0.70	0.18	0.67	0.75	0.14	0.36	0.74	0.43	0.43	0.79	0.43
maximum	0.95	0.99	0.60	0.99	0.99	0.46	0.81	1.00	0.79	0.77	1.00	0.79

Table 6: RICEBs of males and females

Individual poverty. Our RICEB estimates allow us to conduct a poverty analysis directly at the level of individuals in households rather than at the level of aggregate households. Given our particular set-up, such a poverty analysis can simultaneously account for both economies of scale in consumption (through public goods) and within-household sharing patterns (reflecting individuals' bargaining positions). To clearly expose the impact of these two mechanisms, we perform three different exercises. In our first exercise, we compute the poverty rate defined in the usual way, i.e. as the percentage of households having full income that falls below the poverty line, which we fix at 60% of the median full income in our sample of households.[16] This also equals the individual poverty rates if there would be equal sharing and no economies of scale. The results of this exercise are given in Table 7 under the heading "no economies of scale and equal sharing". We would label 12.19% of the individuals (and couples) as poor if we ignored scale economies and assumed that

[16] We remark that, while 60% of the median income is a standard measure of relative poverty (e.g. used in the definition of OECD poverty rates), in our case the poverty rate is calculated on the basis of full income instead of (the more commonly used) earnings or total expenditures. Also, our data set pertains to couples where both spouses participate in the labor market, and so our poverty line will be different from a line based on data that includes households with singles, unemployed or retired members.

household resources are shared equally between males and females.

In a following exercise, we use the same household poverty line but now account for the possibility that household consumption exceeds the expenditures because of economies of scale. In particular, we increase the households' aggregate consumption levels by using the (lower and upper) scale economies estimates that we summarized in Table 3. Again, we assume equal sharing within households. Then, we can compute lower and upper bounds on individual poverty rates while accounting for the specific impact of households' scale economies. We report these results under the heading "with economies of scale and equal sharing" in Table 7. Not surprisingly, we see that poverty rates decrease when compared to the calculations that ignore intrahousehold scale economies; the estimated poverty rate is now between 5.45% (lower bound) and 10.6% (upper bound).

So far, we have computed poverty rates under the counterfactual of equal sharing within households. However, households typically do not split consumption perfectly equally. Therefore, in our third exercise, we compute poverty rates on the basis of our RICEB results summarized in Table 6. Here, we label an individual as poor if his/her RICEB-based estimate falls below the individual poverty line, which we define as half of the poverty line for couples that we used above. Like before, we can compute upper and lower bound estimates for the individual poverty rates. The outcomes are summarized under the heading "with economies of scale and unequal sharing" in Table 7. It is interesting to compare these results with the ones that account for scale economies but assume equal intrahousehold sharing. We conclude that unequal sharing considerably deteriorates the poverty rates, both for the males and the females in our sample. In particular females seems to suffer the most: the lower and upper rates of female poverty equal 11.51% and 24.38%, which is well above the upper bound of 10.60%. In Appendix C, we provide some further insights in these poverty rates by differentiating between households with different characteristics. It illustrates that our method can be used to analyze poverty differences between males and females depending on number of children and region of residence.

These results fall in line with the findings of Cherchye, De Rock, Lewbel and Vermeulen (2015), who also showed that, due to unequal sharing of resources within households, the fraction of individuals living below the poverty line may be considerably greater than the fraction obtained by standard measures that ignore intrahousehold allocations. A main novelty of our analysis is that we also highlight the importance of households' scale economies in assessing individual poverty. For some households/individuals, publicness of consumption may partly offset the negative effect of unequal sharing. As we have shown, our method effectively allows us to disentangle the impact of the two channels.[17]

[17] For the sake of brevity, we focused on the importance of economies of scale in assessing individual poverty. However, our method would also allow us to investigate the role played by economies of scale and unequal sharing in assessing between and within-household consumption inequality (see, e.g., Lise and Seitz, 2011 and Greenwood, Guner, Kocharkov and Santos, 2014, 2016, for alternative methods and applications).

		Households	Males	Females
no economies of scale, equal sharing		12.19	12.19	12.19
with economies of scale and equal sharing	lower bound	5.45	5.45	5.45
	upper bound	10.60	10.60	10.60
with economies of scale and unequal sharing	lower bound	-	8.25	11.51
	upper bound	-	15.75	24.38

Table 7: poverty rates (in %)

Household characteristics and compensation schemes. We can relate the observed inter-household heterogeneity in individual RICEBs to the observable household characteristics that were also taken up in Table 5. Like before, we conduct an interval regression that uses the lower and upper RICEB bounds as dependent variables, as well as a simple OLS regression that uses the average of these bounds. Table 8 shows our results. At this point, it is worth recalling that our RICEB measures capture both scale economies and intrahousehold allocation effects. Greater economies of scale generally lead to higher RICEBs for both the husband and wife, while individual RICEBs benefit in relative terms when the individual's bargaining position improves. The regression results in Table 8 should be interpreted in view of these two channels.

Some interesting patterns emerge from Table 8. A higher relative wage for the female has a significantly positive effect on her share and a negative effect on the male's share. This finding is in line with the existing evidence (and our intuition): when the wife's relative wage goes up, she becomes a more attractive partner on the marriage market. As an implication, her intrahousehold bargaining position improves, and she gets greater control over the household expenses. Next, household income is slightly negatively related for females and, albeit less outspoken, positively related for males (not for the OLS regression). From Table 5, we learned that a higher household income leads to lower scale economies. The new Table 8 adds that this negative effect mainly runs through the female RICEB.

Several other household characteristics also have a significant impact on the individual RICEBs. For example, a higher number of dependent children generally has a positive impact on both the male's and female's consumption shares. Apparently, both household members benefit from the increased public consumption that is associated with having children (as reported in Table 5), albeit that the impact is somewhat stronger for females than for males. Further, we find that the region of residence also has an effect: male RICEBs are generally lower in the North Central and South regions than in the Northeast region, while the opposite holds for female RICEBs. In view of our results in Table 5, this suggests that mainly the females benefit from the greater economies of scale in the North Central and South regions. Finally, a greater difference between the male and female ages seems to be negative for the female and positive for the male, all else equal.

By using the regression results in Table 8, we can compute individual compensation schemes that guarantee the same consumption level in case of marriage dissolution or spousal death. We

	Male		Female	
	Interval	OLS	Interval	OLS
$\log(w_f/w_m)$	-0.203***	-0.204***	0.208***	0.203***
	(0.00308)	(0.00303)	(0.00315)	(0.00329)
log(total income)	0.00885**	0.000799	-0.0351***	-0.0387***
	(0.00376)	(0.00330)	(0.00447)	(0.00402)
husband has a college degree	-0.0229***	-0.0236***	0.0238***	0.0174***
	(0.00411)	(0.00379)	(0.00505)	(0.00472)
one child	0.0264***	0.0270***	0.0331***	0.0304***
	(0.00422)	(0.00356)	(0.00452)	(0.00400)
two children	0.0179***	0.0199***	0.0432***	0.0413***
	(0.00440)	(0.00384)	(0.00452)	(0.00440)
more than two children	0.0235***	0.0284***	0.0288***	0.0388***
	(0.00589)	(0.00506)	(0.00713)	(0.00577)
$31 \leq age_m \leq 40$	-0.00802*	-0.00775**	-0.000780	0.000250
	(0.00451)	(0.00388)	(0.00499)	(0.00425)
$41 \leq age_m \leq 50$	-0.00529	-0.000669	-0.0103*	-0.00274
	(0.00498)	(0.00447)	(0.00581)	(0.00487)
$51 \leq age_m \leq 60$	-0.000673	0.00409	0.00357	0.0111*
	(0.00533)	(0.00488)	(0.00561)	(0.00581)
$61 \leq age_m$	0.0150***	0.0154***	-0.0298***	-0.0158**
	(0.00578)	(0.00513)	(0.00604)	(0.00654)
North Central	-0.0130***	-0.0147***	0.0128**	0.00286
	(0.00454)	(0.00388)	(0.00498)	(0.00441)
South	-0.0168***	-0.0192***	0.00957**	0.00112
	(0.00427)	(0.00359)	(0.00456)	(0.00432)
West	-0.00512	-0.00481	0.000685	-0.000676
	(0.00510)	(0.00419)	(0.00579)	(0.00507)
$age_m - age_f$	0.000667*	0.000316	-0.000820*	-0.00111***
	(0.000393)	(0.000359)	(0.000446)	(0.000413)
$degree_m - degree_f$	-0.000771	-0.000647	0.00256	-0.00253
	(0.00352)	(0.00333)	(0.00420)	(0.00396)
constant	0.485***	0.558***	0.821***	0.862***
	(0.0305)	(0.0266)	(0.0373)	(0.0325)
observations	1138	1138	1138	1138
R-squared		0.937		0.915

robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: individual RICEBs and household characteristics

conclude this section by illustrating this application for the counterfactual situation of a household with (*i*) the male and female of the same age and between 21 and 30 years old, (*ii*) no college degree, (*iii*) a household income that equals the sample average (with log(full income) = 8.399), and (*iv*) an average wage ratio (with $\log(w_f/w_m) = -0.235$). For this household type, we compute male and female RICEBs for alternative scenarios in terms of household size and region of residence, by using the OLS results in Table 8.[18] This expresses the required incomes in the counterfactual situation as fractions of the household's current full potential income (= 4442.622 = exp(8.399)). The results are reported in Tables 9 and 10. The male compensations are always above the female compensations, reflecting the unequal intrahousehold sharing that we documented before.[19] Next, required compensations generally increase with the number of children, consistent with our finding that children give rise to scale economies. Finally, we find variation in compensation schemes across regions, which indicates regional differences in costs-of-living.

	Children = 0	Children = 1	Children = 2	Children > 2
Northeast	0.6127	0.6397	0.6326	0.6411
North Central	0.5980	0.6250	0.6179	0.6264
South	0.5935	0.6205	0.6134	0.6219
West	0.6079	0.6349	0.6278	0.6363

Table 9: male RICEBs as consumption-preserving income compensations

	Children = 0	Children = 1	Children = 2	Children > 2
Northeast	0.4893	0.5197	0.5306	0.5281
North Central	0.4922	0.5226	0.5335	0.5310
South	0.4905	0.5209	0.5317	0.5293
West	0.4887	0.5191	0.5300	0.5275

Table 10: female RICEBs as consumption-preserving income compensations

8 Conclusion

We have presented a novel structural method to empirically identify households' economies of scale that originate from public consumption (defined by Barten scales). We take it that these economies of scale imply gains from marriage, and use the observed marriage behavior to identify households' scale economies under the maintained assumption of marital stability. Our method is intrinsically nonparametric and requires only a single consumption observation per household. In addition,

[18] In principle, we could also have used the interval regression results in Table 5 to compute bounds on the male and female income compensations, but this would have lead to similar conclusions. A more ambitious alternative approach is to directly start from the revealed preference characterization in Proposition 1 to predict household behavior in new decision situations. For compactness, we will not explain this approach here, but it can proceed along the lines of nonparametric counterfactual analysis as explained by Varian (1982) and Blundell, Browning and Crawford (2008).

[19] In this respect, we remark that the male wage is higher than the female wage in the counterfactual situation under consideration (i.e. $\log(w_f/w_m) = -0.235$). This creates gender differences in potential labor incomes, which will at least partly cover the (differences in) required income compensations that we report in Tables 9 and 10.

the method can be implemented through simple linear programming, which is attractive from a practical point of view. Our method produces informative empirical results that give insight into the structure of scale economies for alternative household types. In turn, these findings can be used to address a variety of follow-up questions (e.g. on intrahousehold allocation patterns and individual income compensations in case of marriage dissolution or spousal death).

We have demonstrated alternative uses of our method through an empirical application to consumption data drawn from the PSID, for which we assume that similar households (in terms of age, education, number of children and region of residence) operate on the same marriage market and are characterized by a homogeneous consumption technology. We found that public consumption increases with the number of children living in the household, and that particularly households in the Northeast region of the US experience more economies of scale, while richer households are generally characterized by lower scale economies. Next, we have analyzed intrahousehold allocation patterns of expenditures by computing the "relative costs of equivalent bundles" (RICEBs) for the males and females in our sample, and we showed the relevance of these RICEBs for individual poverty analysis (revealing substantial inequalities between males and females in households with dependent children). We found that the individual RICEBs are significantly related to the intrahousehold wage ratio, the household's full incomes, the number of children, the interspousal age differences and the region of residence. As an implication, the same variables also impact the individual compensation schemes required to guarantee the same consumption level in case of marriage dissolution or wrongful death. For example, we found that for females these compensations (as percentages of actual household incomes) increase with the relative wage (female wage divided by male wage) and number of children, while it decreases with the total income and the age difference (male age minus female age).

A specific feature of our analysis is that we used only a single consumption observation per household. This shows the empirical usefulness of our method even if only cross-sectional household data can be used. In practice, however, panel data sets containing time-series of observations for multiple households are increasingly available. The use of household-specific time-series would allow us to additionally exploit the specific testable implications of our assumption that collective households realize Pareto efficient intrahousehold allocations (under the assumption of time-invariant individual preferences; see Cherchye, De Rock and Vermeulen, 2007, 2011, for detailed discussions). Obviously, this can only enrich the analysis. For example, it would allow us to recover individual indifference curves, which enables the computation of indifference scales as defined by Browning, Chiappori and Lewbel (2013). These indifference scales can be used to compute Hicksian-type income compensations (i.e. for fixed utility levels) in case of divorce or spousal death, which constitute useful complements to the (Slutsky-type) RICEB-based compensations (with fixed consumption levels) that we considered in the current study. In addition, the use of household-specific time-series could also allow us to relax our assumption that observably similar households are characterized by a homogeneous consumption technology, and thus to account for fully unobserved heterogeneity of the household technologies.

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Appendix A: Proof of Proposition 1

Our proof extends the logic of the reasoning in Cherchye, Demuynck, De Rock and Vermeulen (2014) to our particular setting with Barten scales. It proceeds in three steps. In our first step, we derive Lemma 2. In our second step, we use this auxiliary result to prove Proposition 3, which states necessary and sufficient conditions for rationalizability of a data set $\mathcal{D}$. These conditions will be nonlinear in unknowns and therefore difficult to use in practice. In our final step, we start from Proposition 3 to obtain Proposition 1 that we discuss in the main text. This result defines our conditions that are linear in unknowns and necessary for rationalizability of a given data set.

Step 1. For any pair (m, f), consider the following optimization problem for man m :

$$\begin{aligned}\psi_{m,f}(\bar{u}^f) = \max_{q_{m,f}^m, q_{m,f}^f, q_{m,f}} \quad & u^m(q_{m,f}^m, Aq_{m,f}) \\ \text{s.t. } & p_{m,f}q_{m,f} \leq y_{m,f}, \\ & u^f(q_{m,f}^f, Aq_{m,f}) \geq \bar{u}^f\end{aligned}$$

In words, $\psi_{m,f}(\bar{u}^f)$ gives the maximum utility that m can achieve when he is matched with f under the condition that the utility level of f must be at least $\bar{u}^f$. Let $\bar{U}_{m,f}^m$ and $\bar{U}_{m,f}^f$ be the maximum utility possible for m and f, respectively, when matched together. Given that $\bar{u}^f \in [0, \bar{U}_{m,f}^f]$, the function $\psi_{m,f} : [0, \bar{U}_{m,f}^f] \to [0, \bar{U}_{m,f}^m]$ traces out the Pareto frontier for the pair (m, f).

Then, we can prove the next result, which will be instrumental for our following reasoning.

Lemma 2 *The function $\psi_{m,f}(\bar{u}^f)$ is strictly decreasing and continuous over the interval $[0, \bar{U}_{m,f}^f]$.*

Proof. Consider two utility levels $\bar{u}^f, \bar{u}^{f'}$ such that $0 \leq \bar{u}^f < \bar{u}^{f'} \leq \bar{U}_{m,f}^f$. By strict monotonicity of the individual utility functions, we have $\psi_{m,f}(\bar{u}^{f'}) \leq \psi_{m,f}(\bar{u}^f)$. This is because every solution with utility level $\bar{u}^{f'}$ is also feasible with the utility level $\bar{u}^f$. Let $q_{m,f}^f$ be the woman's share for the optimization problem with utility level $\bar{u}^{f'}$. Since $0 < \bar{u}^{f'}$, we have $0 < q_{m,f}^f$ by assumption. By continuity and strict monotonicity of u^f, it is possible to take a small portion of $q_{m,f}^f$ and transfer it to m, such that the utility of f is still greater than or equal to $\bar{u}^f$ and the utility of m is strictly greater than $\psi_{m,f}(\bar{u}^{f'})$. Thus, if $0 \leq \bar{u}^f < \bar{u}^{f'} \leq \bar{U}_{m,f}^f$, then $0 \leq \psi_{m,f}(\bar{u}^{f'}) < \psi_{m,f}(\bar{u}^f) \leq \bar{U}_{m,f}^m$. To show that $\psi_{m,f}$ is continuous, consider the following optimization problem for woman f:

$$\begin{aligned}\xi_{m,f}(\bar{u}^m) = \max_{q_{m,f}^m, q_{m,f}^f, q_{m,f}} \quad & u^f(q_{m,f}^f, Aq_{m,f}) \\ \text{s.t. } & p_{m,f}q_{m,f} \leq y_{m,f}, \\ & u^m(q_{m,f}^m, Aq_{m,f}) \geq \bar{u}^m\end{aligned}$$

The function $\xi_{m,f}$ is the inverse of the function $\psi_{m,f}$. Assume that $\xi_{m,f}(\bar{u}^m) = \bar{u}^f$, and let ($q_{m,f}^m$, $q_{m,f}^f$, $Aq_{m,f}$) be the solution to the optimization problem for woman f that we introduced above.

Hence, this bundle satisfies all the restrictions for the optimization problem for man m, so that $\psi_{m,f}(\bar{u}^f) \geq \bar{u}^m$. We claim that $\psi_{m,f}(\bar{u}^f) = \bar{u}^m$. This can be shown by contradiction. Suppose $\psi_{m,f}(\bar{u}^f) > \bar{u}^m$, and let $(q^m_{m,f}, q^f_{m,f}, Aq_{m,f})$ be the solution to man m's optimization problem. This allocation is also feasible for woman f's optimization problem. Further, since $q^m_{m,f}$ is strictly positive for at least one good, we can transfer a small amount to f such that m's utility is still greater than or equal to $\bar{u}^m$. This allows f to reach a utility level that is strictly above $\bar{u}^f$. This implies $\xi_{m,f}(\bar{u}^m) > \bar{u}^f$, which is a contradiction. We conclude that $\psi_{m,f}$ is a strictly increasing and everywhere invertible function from an interval to an interval. Hence, it is also continuous. ■

By using Lemma 2, we can rephrase the no blocking pair criterion in an alternative form. More specifically, given that the function $\psi_{m,f}(\overline{u}^f)$ is continuous and strictly decreasing, it is easy to see that the no blocking pair criterion in Section 3 is equivalent to the requirement that, for any man m and woman f, there must exist at least one combination of $U^m_{m,f}$ and $U^m_{m,f}$ such that

$$U^m_{m,f} = \psi_{m,f}(U^f_{m,f}),$$
$$U^m_{m,f} \leq u^m(q^m_{m,\sigma(m)}, Aq_{m,\sigma(m)}) \text{ and } U^f_{m,f} \leq u^f(q^f_{\sigma(f),f}, Aq_{\sigma(f),f}). \tag{8}$$

Step 2. By using the alternative formulation of the no blocking pair criterion in (8), we can derive the following result, which states necessary and sufficient conditions for rationalizability of a data set $\mathcal{D}$.[20]

Proposition 3 *The data set $\mathcal{D}$ is rationalizable by a stable matching if and only if there exists a $K \times K$ matrix A with diagonal entries $0 \leq a_k \leq 1$ for all $k \in \{1, 2, \cdots, K\}$ and,*

(a) for each matched pair $(m, \sigma(m))$, nonlabor incomes n_m, $n_{\sigma(m)} \in \mathbb{R}$ that satisfy

$$n_{m,\sigma(m)} = n_m + n_{\sigma(m)},$$

(b) for each matched pair $(m, \sigma(m))$, individual quantities $q^m_{m,\sigma(m)}, q^{\sigma(m)}_{m,\sigma(m)} \in \mathbb{R}^K_+$ that satisfy

$$q^m_{m,\sigma(m)} + q^{\sigma(m)}_{m,\sigma(m)} = (I - A)q_{m,\sigma(m)},$$

(c) for each pair (m, f), individual quantities $q^m_{m,f}, q^f_{m,f} \in \mathbb{R}^K_+$ and public quantities $Aq_{m,f} \in \mathbb{R}^K_+$ that satisfy

$$p_{m,f}(q^m_{m,f} + q^f_{m,f}) + p_{m,f}Aq_{m,f} = y_{m,f}$$

(d) for each m and f, private quantities $q^m_{m,\phi}, q^f_{\phi,f} \in \mathbb{R}^K_+$ and public quantities $Aq_{m,\phi}, Aq_{\phi,f} \in \mathbb{R}^K_+$

[20] The numbers $U^m_{m,f}, U^m_{m,\phi}, U^f_{m,f}, U^f_{\phi,f}$ and $\delta_{m,f}, \delta_{m,\phi}, \lambda_{m,f}, \lambda_{\phi,f}$ in Proposition 3 are commonly referred to as "Afriat numbers" in the literature on nonparametric revealed preference analysis (after Afriat, 1967; see also Varian, 1982). In a similar vein, the inequalities under condition (1) are known as "Afriat inequalities".

that satisfy

$$p_{m,\phi} q^m_{m,\phi} + p_{m,\phi} A q_{m,\phi} = y_{m,\phi} \text{ and}$$
$$p_{\phi,f} q^f_{\phi,f} + p_{\phi,f} A q_{\phi,f} = y_{\phi,f},$$

(e) for each pair (m, f), personalized prices $p^m_{m,f}, p^f_{m,f} \in \mathbb{R}^K_{++}$ that satisfy

$$p^m_{m,f} + p^f_{m,f} = p_{m,f},$$

and strictly positive numbers $U^m_{m,f}, U^m_{m,\phi}, U^f_{m,f}, U^f_{\phi,f}$ and $\delta_{m,f}, \delta_{m,\phi}, \lambda_{m,f}, \lambda_{\phi,f}$ that satisfy, for all males $m \in M$ and females $f \in F$,

(i) the inequalities

$$U^m_{m,f} - U^m_{m,\phi} \leq \delta_{m,\phi}(p_{m,\phi}(q^m_{m,f} - q^m_{m,\phi}) + p_{m,\phi}(Aq_{m,f} - Aq_{m,\phi})),$$
$$U^m_{m,f} - U^m_{m,f'} \leq \delta_{m,f'}(p_{m,f'}(q^m_{m,f} - q^m_{m,f'}) + p^m_{m,f'}(Aq_{m,f} - Aq_{m,f'})),$$
$$U^m_{m,\phi} - U^m_{m,f'} \leq \delta_{m,f'}(p_{m,f'}(q^m_{m,\phi} - q^m_{m,f'}) + p^m_{m,f'}(Aq_{m,\phi} - Aq_{m,f'})),$$

and

$$U^f_{m,f} - U^f_{\phi,f} \leq \lambda_{\phi,f}(p_{\phi,f}(q^f_{m,f} - q^f_{\phi,f}) + p^f_{\phi,f}(Aq_{m,f} - Aq_{\phi,f})),$$
$$U^f_{m,f} - U^f_{m',f} \leq \lambda_{m',f}(p_{m',f}(q^f_{m,f} - q^f_{m',f}) + p^f_{m',f}(Aq_{m,f} - Aq_{m',f})),$$
$$U^f_{\phi,f} - U^f_{m',f} \leq \lambda_{m',f}(p_{m',f}(q^f_{\phi,f} - q^f_{m',f}) + p^f_{m',f}(Aq_{\phi,f} - Aq_{m',f})),$$

(ii) the individual rationality restrictions

$$U^m_{m,\sigma(m)} \geq U^m_{m,\phi} \text{ and}$$
$$U^f_{\sigma(f),f} \geq U^f_{\phi,f},$$

(iii) and the no blocking pair restrictions

$$U^m_{m,\sigma(m)} \geq U^m_{m,f} \text{ and}$$
$$U^f_{\sigma(f),f} \geq U^f_{m,f}.$$

Proof.

-
- **Necessity.** Assume that there exist utility functions u^m and u^f for all m and $f \in F$ such that the data set is rationalizable under stable matching. Then, we need to show that the inequalities and restrictions in Proposition 3 hold true.

As a first step, consider the optimization problems underlying our individual rationality constraints for each male m and female f, i.e.

$$(q^m_{m,\phi}, Aq_{m,\phi}) = \arg\max_{q^m, Aq} u^m(q^m, Aq) \text{ s.t. } p_{m,\phi}(q^m + Aq) \leq y_{m,\phi},$$
$$(q^f_{\phi,f}, Aq_{\phi,f}) = \arg\max_{q^f, Aq} u^f(q^f, Aq) \text{ s.t. } p_{\phi,f}(q^f + Aq) \leq y_{\phi,f}.$$

The associated first order conditions are

$$\frac{\partial u^m(q^m_{m,\phi}, Aq_{m,\phi})}{\partial q^m} \leq \delta_{m,\phi} p_{m,\phi},$$
$$\frac{\partial u^m(q^m_{m,\phi}, Aq_{m,\phi})}{\partial Aq} \leq \delta_{m,\phi} p_{m,\phi},$$
$$\frac{\partial u^f(q^f_{\phi,f}, Aq_{\phi,f})}{\partial q^f} \leq \lambda_{\phi,f} p_{\phi,f},$$
$$\frac{\partial u^f(q^f_{\phi,f}, Aq_{\phi,f})}{\partial Aq} \leq \delta_{\phi,f} p_{\phi,f}.$$

As a following step, consider the optimization problem underlying our no blocking pairs criterion. For every unmatched pair (m, f), we have

$$(q^m_{m,f}, q^f_{m,f}, Aq_{m,f}) = \arg\max_{q^m, Aq_{m,f}} u^m(q^m, Aq_{m,f})$$
$$\text{s.t. } p_{m,f}(q^m + q^f) + p_{m,f} Aq_{m,f} \leq y_{m,f}$$
$$\text{and } u^f(q^f, Aq_{m,f}) \geq U^f_{m,f},$$

with corresponding first order conditions

$$\frac{\partial u^m(q^m_{m,f}, Aq_{m,f})}{\partial q^m} \leq \delta_{m,f} p_{m,f},$$
$$\mu_{m,f} \frac{\partial u^f(q^f_{m,f}, Aq_{m,f})}{\partial q^f} \leq \delta_{m,f} p_{m,f},$$
$$\frac{\partial u^m(q^m_{m,f}, Aq_{m,f})}{\partial Aq_{m,f}} + \mu_{m,f} \frac{\partial u^f(q^f_{m,f}, Aq_{m,f})}{\partial Aq_{m,f}} \leq \delta_{m,f} p_{m,f}.$$

Then, let $\lambda_{m,f} = \frac{\delta_{m,f}}{\mu_{m,f}}$, $\frac{\partial u^f(q^f_{m,f}, Aq_{m,f})}{\partial Aq} = \lambda_{m,f} p^f_{m,f}$ and $p^m_{m,f} = p_{m,f} - p^f_{m,f}$. This implies, $\frac{\partial u^m(q^m_{m,f}, Aq_{m,f})}{\partial Aq_{m,f}} \leq \delta_{m,f} p^m_{m,f}$. Since u^m and u^f are concave functions, for any $q^{m\prime}$, $q^{m\prime\prime}$, $q^{f\prime}$, $q^{f\prime\prime}$,

$Aq^{'}$, $Aq^{''} \in \mathbb{R}^K_+$, we have

$$u^m(q^{m'}, Aq^{'}) - u^m(q^{m''}, Aq^{''}) \leq \frac{\partial u^m(q^{m''}, Aq^{''})}{\partial q^m}(q^{m'} - q^{m''}) + \frac{\partial u^m(q^{m''}, Aq^{''})}{\partial Aq}(Aq^{'} - Aq^{''})$$
$$u^f(q^{f'}, Aq^{'}) - u^f(q^{f''}, Aq^{''}) \leq \frac{\partial u^f(q^{f''}, Aq^{''})}{\partial q^f}(q^{f'} - q^{f''}) + \frac{\partial u^f(q^{f''}, Aq^{''})}{\partial Aq}(Aq^{'} - Aq^{''})$$

Now define $U^m_{m,f} = u^m(q^m_{m,f}, Aq_{m,f})$ for all $m \in M, f \in F \cup \{\phi\}$ and $U^f_{m,f} = u^f(q^m_{m,f}, Aq_{m,f})$ for all $f \in F, m \in M \cup \{\phi\}$. This directly obtains the rationalizability conditions (1)-(3) in Proposition 3 (when using formulation (8) for the no blocking pair criterion).

- **Sufficiency.** Assume that conditions (a)-(e) and (1)-(3) in Proposition 3 hold true. We have to show that there exist concave and continuous utility functions v^m and u^f for all $m \in M$ and $f \in F$ that obtain rationalizability of the data set $\mathcal{D}$. To obtain this conclusion, we define

$$u^m(q^m, Aq) = \min_{f \in F \cup \{\phi\}} [U^m_{m,f} + \delta_{m,f}(p_{m,f}(q^m - q^m_{m,f}) + P^m_{m,f}(Aq - Aq_{m,f}))]$$
$$u^f(q^f, Aq) = \min_{m \in M \cup \{\phi\}} [U^f_{m,f} + \lambda_{m,f}(p_{m,f}(q^f - q^f_{m,f}) + P^f_{m,f}(Aq - Aq_{m,f}))]$$

By using a similar argument as Varian (1982), we obtain $u^m(q^m_{m,f}, Aq_{m,f}) = U^m_{m,f}$ and $u^f(q^f_{m,f}, Aq_{m,f}) = U^f_{m,f}$. Then, by using a direct adaptation of the argument in Cherchye, De Rock and Vermeulen (2011), we can show that the utility functions u^m and u^f defined above rationalize the data set under stable matching (i.e. the data solve the optimization problems underlying our stability criteria for these functions u^m and u^f).

■

Step 3. By starting from Proposition 3, we can derive Proposition 1 in the main text, which gives necessary conditions for rationalizability that are linear in unknowns. The proof of Proposition 1 goes as follows:

Proof. The individual rationality condition (1) in Proposition 1 is obtained from combining the individual rationality restrictions (2) with the inequalities (1) in Proposition 3. In particular, we get

$$0 \leq p_{m,\phi}(q^m_{m,\sigma(m)} - q^m_{m,\phi}) + p_{m,\phi}(Aq_{m,\sigma(m)} - Aq_{m,\phi}) \text{ and}$$
$$0 \leq p_{\phi,f}(q^f_{\sigma(f),f} - q^f_{\phi,f}) + p_{\phi,f}(Aq_{\sigma(f),f} - Aq_{\phi,f}),$$

which gives

$$y_{m,\phi} \leq p_{m,\phi}q^m_{m,\sigma(m)} + p_{m,\phi}Aq_{m,\sigma(m)} \text{ and}$$
$$y_{\phi,f} \leq p_{\phi,f}q^f_{\sigma(f),f} + p_{\phi,f}Aq_{\sigma(f),f}.$$

Similarly, the no blocking pair restriction (2) in Proposition 1 is obtained by combining the no blocking pair restrictions (3) with (1) in Proposition 3. In this case, we obtain

$$0 \leq p_{m,f}(q^m_{m,\sigma(m)} - q^m_{m,f}) + p^m_{m,f}(Aq_{m,\sigma(m)} - Aq_{m,f}) \text{ and}$$
$$0 \leq p_{m,f}(q^f_{\sigma(f),f} - q^f_{m,f}) + p^f_{m,f}(Aq_{\sigma(f),f} - Aq_{m,f}),$$

which add up to (using condition (e) in Proposition 3)

$$y_{m,f} \leq p_{m,f}q^m_{m,\sigma(m)} + p^m_{m,f}Aq_{m,\sigma(m)} + p_{m,f}q^f_{\sigma(f),f} + p^f_{m,f}Aq_{\sigma(f),f}, \text{ or}$$
$$y_{m,f} \leq p_{m,f}q^m_{m,\sigma(m)} + p_{m,f}q^f_{\sigma(f),f} + p_{m,f}A\max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\},$$

where $\max\{q_{m,\sigma(m)}, q_{\sigma(f),f}\}$ defines the element-by-element maximum, i.e. $q = \max\{q^1, q^2\}$ with $q_k = \max\{q^1_k, q^2_k\}$ for all k. ■

Appendix B: Supplementary data information

Composition of Hicksian good (source: PSID codebook)

- Food expenditures: expenditures for food at home, delivered and eaten away from home.
- Housing expenditures: expenditures for mortgage and loan payments, rent, property tax, insurance, utilities, cable TV, telephone, internet charges, home repairs and home furnishings.
- Transportation expenditures: expenditures for vehicle loan, lease, and down payments, insurance, other vehicle expenditures, repairs and maintenance, gasoline, parking and car pool, bus fares and train fares, taxicabs and other transportation.
- Education expenditures: total school-related expenses.
- Childcare expenditures: total expenditures on childcare.
- Health care expenditures: expenditures for hospital and nursing home, doctor, prescription drugs and insurance.
- Clothing expenditures: total expenses on clothing and apparel, including footwear, outerwear, and products such as watches or jewelry.
- Recreation expenditures: total expenses on trips and vacations, including transportation, accommodations, recreational expenses on trips, recreation and entertainment, including tickets to movies, sporting events, and performing arts and hobbies including exercise, bicycles, trailers, camping, photography, and reading materials.

Size of marriage markets

Tables 11-14 present the sizes of the marriage markets that we consider in our empirical application.

	Degree = 0					Degree = 1				
nr of children	0	1	2	> 2	Total	0	1	2	> 2	Total
age ≤ 30	3	3	3	1	10	18	3	1	0	22
31 ≤ age ≤ 40	7	8	6	8	29	16	8	15	6	45
41 ≤ age ≤ 50	2	1	2	1	6	4	6	21	8	39
51 ≤ age ≤ 60	6	1	0	0	7	25	6	4	1	36
61 ≤ age	3	0	0	0	3	16	0	1	0	17
total	21	13	11	10	55	79	23	42	15	159

Table 11: marriage market sizes for the Northeast region

	Degree = 0					Degree = 1				
nr of children	0	1	2	> 2	Total	0	1	2	> 2	Total
age ≤ 30	18	12	6	3	39	28	7	8	0	43
31 ≤ age ≤ 40	11	6	17	13	47	21	15	33	15	84
41 ≤ age ≤ 50	6	5	4	3	18	10	5	20	12	47
51 ≤ age ≤ 60	16	2	0	1	19	24	4	7	1	36
61 ≤ age	2	0	0	0	2	19	0	0	0	19
total	53	25	27	20	125	102	31	68	28	229

Table 12: marriage market sizes for the North Central region

	Degree = 0					Degree = 1				
nr of children	0	1	2	> 2	Total	0	1	2	> 2	Total
age ≤ 30	16	13	11	4	44	35	13	8	0	56
31 ≤ age ≤ 40	10	12	29	17	68	28	29	38	25	120
41 ≤ age ≤ 50	7	12	6	1	26	10	25	23	15	73
51 ≤ age ≤ 60	14	2	0	1	17	30	7	7	0	44
61 ≤ age	10	0	0	0	10	38	1	1	0	40
total	57	39	46	23	165	141	75	77	40	333

Table 13: marriage market sizes for the South region

	Degree = 0					Degree = 1				
nr of children	0	1	2	> 2	Total	0	1	2	> 2	Total
age ≤ 30	12	7	4	0	23	19	11	2	0	32
31 ≤ age ≤ 40	4	3	9	9	25	16	20	18	2	56
41 ≤ age ≤ 50	6	2	5	9	22	4	4	16	12	36
51 ≤ age ≤ 60	10	2	0	0	12	21	1	2	8	32
61 ≤ age	4	0	0	0	4	12	0	0	1	13
total	36	14	18	18	86	72	36	38	23	169

Table 14: marriage market sizes for the West region

Budget shares

For the different subgroups of households, Tables 15-18 report average budget shares of the five consumption goods that we consider.

	Children = 0	Children = 1	Children = 2	Children > 2	Total
female leisure	30.37	28.82	27.19	26.34	28.74
male leisure	35.53	35.20	34.68	32.65	34.87
female household work	5.36	5.94	6.23	7.77	6.01
male household work	4.03	4.07	4.78	5.06	4.36
market good	24.72	25.97	27.12	28.18	26.02

Table 15: budget shares (in %) by number of children

	Degree = 0	Degree = 1	Total
female leisure	29.01	28.61	28.74
male leisure	33.32	35.62	34.87
female household work	6.31	5.86	6.01
male household work	4.23	4.43	4.36
market good	27.14	25.48	26.02

Table 16: budget shares (in %) by husband's college degree

	Northeast	North Central	South	West	Total
female leisure	29.62	28.64	28.41	28.79	28.74
male leisure	34.14	35.10	35.02	34.87	34.87
female household work	6.27	6.19	5.94	5.69	6.01
male household work	4.76	4.31	4.12	4.57	4.36
market good	25.21	25.76	26.52	26.09	26.02

Table 17: budget shares (in %) by region of residence

	≤ 30	31-40	41-50	51-60	>60	Total
female leisure	29.73	28.95	27.80	27.91	29.09	28.74
male leisure	33.22	34.24	36.03	36.49	36.06	34.87
female household work	5.97	6.05	5.74	6.09	6.43	6.01
male household work	4.23	4.17	4.51	5.11	3.86	4.36
market good	26.85	26.59	25.92	24.40	24.55	26.02

Table 18: budget shares (in %) by age category of husband

Appendix C: Poverty rates for specific household types

Tables 19 and 20 present poverty rates similar to the ones in Table 7, but now distinguishing between households with different numbers of children (Table 19) and regions of residence (Table 20).

		Children = 0	Children = 1	Children = 2	Children > 2
No scale economies and equal sharing		12.30	10.02	14.68	12.99
With economies of scale and equal sharing	lower bound	6.24	3.52	4.59	6.21
	upper bound	10.34	8.20	12.23	10.73
With economies of scale and unequal sharing: male	lower bound	11.41	4.69	6.12	6.21
	upper bound	19.61	12.50	12.54	14.69
With economies of scale and unequal sharing: female	lower bound	11.59	9.38	12.54	12.43
	upper bound	22.46	22.66	26.61	28.81

Table 19: poverty rates (in %) for different household compositions

		Northeast	North Central	South	West
No scale economies and equal sharing		16.36	13.28	11.85	12.16
With economies of scale and equal sharing	lower bound	6.07	6.45	6.42	5.49
	upper bound	15.42	10.73	10.24	10.98
With economies of scale and unequal sharing: male	lower bound	6.54	11.58	8.03	6.67
	upper bound	19.62	16.10	13.86	18.82
With economies of scale and unequal sharing: female	lower bound	14.02	13.28	12.65	9.02
	upper bound	25.23	26.27	23.49	25.88

Table 20: poverty rates (in %) for different regions