It's complicated: A Non–parametric Test of Preference Stability between Singles and Couples

Stefan Hubner[1]

[1]*Department of Economics, University of Bristol**

July 2020

Abstract *This paper develops a method to use data from singles in a non–parametric collective household setting. We use it to test the controversial assumption of preference stability between singles and couples. Our test allows for unobserved heterogeneity by defining finite-dimensional types of households according to their revealed preference relations. We show how to derive a test statistic by constructing hypothetical matches of heterogeneous individuals into different types of households using tools from stochastic choice theory. We strongly reject the preference–stability hypothesis based on consumption data from the Dutch LISS, the Russian RLMS, and the Spanish ECPF panels.*

JEL Codes: *D12, D13, J12*
Keywords: *Collective model, Preference Stability, Collective Axiom of Revealed Preference, Stochastic Choice, Random Utility Models*

1 Introduction

Measuring poverty levels, quantifying the effects of socio-economic policies on individuals, and generally understanding the mechanisms of individual decision making are pivotal challenges for economists and economic policy makers. Most of the relevant datasets, however, do not feature granular enough information to meet these challenges because a majority of individuals live in collective units, such as households

*Click *here* or onto the title to download the most recent version. Stefan Hubner (stefan.hubner@bristol.ac.uk) gratefully acknowledges financial support from the Netherlands Organisation for Scientific Research (NWO) through a TOP Grant. The author would also like to thank Arthur van Soest, Laurens Cherchye, Frederic Vermeulen, Stefan Hoderlein, Ian Crawford, Yuichi Kitamura, Jörg Stoye, John Quah, Martin Browning, and various participants from the Heterogeneity in Supply and Demand workshop (2016) for their helpful comments.

or families. Trying to get inside this black box, without observing information about resource sharing within the household, economists make two prevalent assumptions.[1] First, preferences are independent of the state of an individual's relationship: single or couple. Second, preference heterogeneity is largely described by two types: men and women.

In this paper, we construct a test of the former and thoroughly extend the latter. We will do so without observing any transitions between relationship states, and without observing more than aggregate household-level choices. In order to avoid rejecting the hypothesis based on auxiliary restrictions, the test is fully non-parametric and allows for a heterogeneous population. Preference homogeneity is particularly restrictive in the context of the collective model since it not only requires every individual to have the same preferences but also assumes that any two individuals matched as a couple would arrive at the exact same sharing of resources. Instead, here we specify a *collective random utility model* with continuous consumption and an arbitrary dimension of unobserved distribution factors and preference parameters.[2] We then construct discrete heterogeneous household types for both couples and singles in a way that ensures that any two households which are not distinguishable in terms of their preferences without a functional form restriction are equivalent. The test is then constructed by considering the population of rational couples, satisfying the Collective Axiom of Revealed Preference (Cherchye, De Rock & Vermeulen, 2007), and the population of rational singles, satisfying the Strong Axiom of Revealed Preference (Afriat, 1967; Varian, 1982), as a baseline. Observing only their respective distributions of consumption choices, we ask the question if these distributions could have been generated from an unobserved combination of *hypothetical matches* between different types of individuals into a mutually coherent household. We show that, under the null hypothesis of stable preferences, such a *stochastic rationalisation* of the data exists.

A difficulty when using or testing preference stability is the presence of consump-

[1]Cf. the seminal work of: Browning, Chiappori & Lewbel (2013), Lewbel & Pendakur (2008) for identification of resource shares based on single households, Mazzocco, Ruiz & Yamaguchi (2014), Voena (2015), Gayle & Shephard (2019) for identification in the context of inter-temporal models, and Chiappori, McCann & Nesheim (2009), Cherchye *et al.* (2017) endogenous marriage market matching models, respectively.

[2]Unobserved distribution factors are random variables effecting the bargaining power, but not the preferences of an individual; for example desirability on the marriage market (Hubner, 2018).

tion externalities. Without further assumptions, they prohibit disentangling adjustments of consumption behaviour due to preference changes from the acquired possibility of consuming a good publicly as a couple, i.e. changes in Lindahl prices. For example, consider individuals with stable preferences commuting to work by car. While as a single they have to pay market prices for gasoline, as a couple they can share the burden and consequently consume more other goods, which could lead us to believe that preferences have changed. For this reason, for our baseline setup we consider a generalisation of the Beckerian caring model (Becker, 1981), which restricts us to only consider strictly private goods for the empirical test. As an extension, we then present a modification of the standard model in which we allow for externalities (public goods) by adapting a linear household production function. While the production technology is not identified in our setting, we calibrate the model using parameter estimates obtained by Cherchye, De Rock & Vermeulen (2012a).

In order to identify preference relations for singles and couples, we make use of (short) panel data and a common time-homogeneity of preferences assumption. We apply our test to three popular datasets: the *Dutch Longitudinal Internet Studies for the Social Sciences (LISS)*, the *Russian Longitudinal Monitoring Survey (RLMS)*, and the *Spanish Continuous Family Expenditure Survey (Encuesta Continua de Presupuestos Familiares, ECPF)* used by Cherchye, De Rock & Vermeulen (2012b), Cherchye, De Rock & Vermeulen (2011), and Adams *et al.* (2014), respectively, in the context of the collective model. We consistently reject the hypothesis of preference stability for all these datasets for both private and public goods.

In contrast to the discrete approach, we propose in this paper, testing preference restrictions in a continuous setting is often based on the Slutsky matrix which requires estimation of household demands and their derivatives. Browning & Chiappori (1998) construct a test of collective rationality based on a parametric almost ideal demand system with additive measurement errors. Similar to this, Brugler (2016) estimates a parametric quadratic ideal demand system (Banks, Blundell & Lewbel, 1997) in a setting without preference heterogeneity and compares the parameter estimates for single men, single women and couples to draw conclusions about preference stability. While almost ideal demand systems provide a flexible functional parametric form where parameter restrictions can be easily tested, the potential for model misspecification and consequential type I errors caused by an inconsistent specification of the functional form restriction can be problematic. In addition to this, even in a fully parametric setting, identification of continuous demand systems in the presence of general unobserved heterogeneity is difficult due to the structure of the collective model, which leads to demands that are non-separable with respect to unobserved preference and bargaining heterogeneity. Also in a continuous choice setting, Hubner (2018) develops a non-parametric collective random utility model and derives restrictions for non-parametric identification of idiosyncratic utility functions and Pareto weights by showing global invertibility of demands, under the assumption of observed private demands. We do not require such a strong form of identification for our test.

To our knowledge, the use of singles data in the context of the fully non-parametric way to model collective households using revealed preference restrictions (Cherchye, De Rock & Vermeulen, 2007, 2009) is novel. The advantage of a revealed preference based approach is that it allows us to use a stochastic random utility and random distribution factor version of the collective model without requiring global invertibility. Revealed stochastic preference settings have recently been used in the context of the unitary consumption model. Hoderlein & Stoye (2014) consider the weak axiom of revealed preference in the unitary model. In particular, they use the fact that demands of a heterogeneous population observed in a given price regime can be characterised as random variables supported on a normalised budget set. Observing the same population in different price regimes (repeated cross-sections), one can then use copula techniques to derive (Frechet-Hoeffding) bounds on the probability that the population behaves irrationally, i.e. is not in line with the weak axiom. Kitamura & Stoye (2018); Deb *et al.* (2017) integrate this approach into the stochastic choice framework of McFadden & Richter (1991) and McFadden (2005) by fully discretising budget sets using partitions which contain all the relevant information to test the strong axiom of revealed preference.

The construction of our test statistic is closely related to these approaches. We show that the large sample theory developed in Kitamura & Stoye (2018) applies to our test statistic and use their results for our statistical inference. We complement this by implementing a fast, parallel non-negative least squares algorithm which leverages the sparsity of the computational problem in Haskell and conduct a simulation study to evaluate finite sample size and power of the test statistic in our setting.

2 Test Design

We start by specifying a collective random utility model with two-person households. Each spouse $r \in \{f, m\}$ consumes a bundle of goods from a finite set of alternatives which is a proper subset of $\mathbb{R}^L_+$. We denote continuous individual private consumption by x^r. Further, let $x^c_{i,t} = x^f_{i,t} + x^m_{i,t} \in \mathbb{R}^L_+$ be continuous household consumption chosen by household $i \in I_N$ in period $t \in I_T$. We assume that a household, characterised by observed (p_t, w_t) and unobserved $\varepsilon^c = (\varepsilon^m, \varepsilon^f, \varepsilon^\mu)$, each elements of a Polish space[3], arrives at this consumption bundle by having maximised its collective random utility

$$\max_{x^f, x^m} \left\{ u^m(x^m, x^f, \varepsilon^m) + \mu(p, \varepsilon^\mu) u^f(x^f, x^m, \varepsilon^f) \right\} \tag{1}$$

$$\text{s.t. } x^f + x^m \in B_t = \left\{ x \mid p_t x \leq w_t \right\},$$

where μ is the relative bargaining power of spouse f (Chiappori, 1988, 1992). By introducing the possibly infinite-dimensional random variable ε^c we allow each household to optimise a different objective function according to idiosyncratic preferences and distribution factors.[4] For each period $t \in I_T$ we observe expenditures for a given good $l \in I_L$ denoted by $p_{t,l} x^c_{i,t,l}$. Observing prices p_t then allows us to calculate the vector of continuous household consumption $x^c_{i,t}$ for each household $i \in I_N$.

Now consider instead a single household $r \in \{f, m\}$ who, under the stable preference assumption, maximises the same $u^r(x^r, x^{r'}, \varepsilon^r)$ subject to the constraint $x^r \in B_t$ according to the standard unitary model. For them, the spouse's consumption $x^{r'}$ is zero. Thus for single households we conveniently observe $x^c = x^r$. Conversely, due to potential complementaries arising from joint consumption of a good with a potential partner, without further restrictions, these zeros will cause an ill-posed utility maximisation problem for single households. Thus, in order to model singles in a way that makes them informative for a couple's consumption behaviour we make the

[3]It can be shown that any preference relation can be expressed as an infinite–dimensional vector of random variables, from which one can construct a random utility function.

[4]Note that, this idiosyncratic characterisation of individuals renders the requirement of assigned gender and heterosexuality, traditionally used as the only form of heterogeneity, redundant. In our exposition we will, nevertheless, retain the commonly used labels f and m for readability.

following separability assumption.

Assumption 1. *Let the* $(L-1)$*-dimensional vector of marginal rates of substitutions for* $r \in \{f, m\}$ *be denoted as* $MRS^r(x^r, x^{r'})$ *with components* $MRS^r_l(x^r, x^{r'}) = \frac{\partial u^r / \partial x^r_l}{\partial u^r / \partial x^r_L}$ *for* $l = 1, \ldots, L-1$. *Then for* $r \neq r'$ *we have* $dMRS^r(x^r, x^{r'})/dx^{r'} = 0_{L-1,L-1}$.

This is standard assumption and required whenever preference stability is used as an identification strategy in the collective model. It states that the marginal rates of substitution for own good consumption does not depend on the spouse's consumption. A sufficient condition for this is separability of the form $u^r(x^r, x^{r'}, \varepsilon^r, \varepsilon^{r'}) = G(g(x^r, \varepsilon^r), x^{r'}, \varepsilon^{r'})$ for any two differentiable, increasing, real-valued functions G and g. While this assumption allows for positive consumption externalities, it restricts the way the behaviour of a person is altered when entering or exiting a relationship. For example, it rules out non-cooperative, strategic behaviour of individuals towards their spouse. This assumption nests popular specifications such as the egoistic model $u^r = g$, but also the Beckerian caring model with altruistic preferences (Becker, 1981). In this specification, utilities of one spouse are defined in terms of own-good consumption and the utility of the spouse, i.e. $u^r(x^r, \varepsilon^r) = W(U^r(x^r, \varepsilon^r), U^{r'}(x^{r'}, \varepsilon^{r'}))$ where U^f and U^m are real-valued sub-utility functions with the usual properties and W is a strictly increasing, differentiable real-valued function.[5] In the baseline setting, we make this assumption to disentangle separability from stable preferences, or otherwise, we would test both assumptions jointly. In either case, a rejection implies that preferences cannot be treated as independent of the relationship status. In Section 5 we discuss an extension of this general setting using a homogenoeus household production technology and present results for public goods as a robustness check.

In the collective model, demands of each spouse are in general not observable and thus their individual preferences are not identified directly from data of cohabiting couples. Using the *stable preference assumption*, how can we exploit information about single households in order to identify u^f and u^m?

To answer this question, we first characterise consumers in terms of their finite-dimensional revealed preference relations. Both the collective and the unitary model impose restrictions on how both household and individual demands must change with

[5]We can write $u^r(x^r, \varepsilon^r) = u^r(x^r, x^{r'}, \varepsilon^r, \varepsilon^{r'})$ because the Beckerian model is observationally equivalent with egoistic individual utility functions in the collective model.

respect to relative price changes. These sets of restrictions are known as the Collective Axiom of Revealed Preference and the Strong Axiom of Revealed Preference, both defined in Appendix A.1. The axioms allow us to partition unobserved heterogeneity in the following way. Let $\mathcal{E}^r = \bigcup_{k_r=1}^{K_r} \mathcal{E}_{k_r}$ such that for all $r \in \{c, f, m\}$ and for all $k_r \in I_{K_r}$ it holds that for any $\varepsilon^r_{k_r}, \xi^r_{k_r} \in \mathcal{E}_{k_r}$ we have $R^r(\varepsilon^r_{k_r}) = R^r(\xi^r_{k_r})$ where R^r are the preference relations resulting from our random utility model (4) with household utility evaluated at $u^m(x^m, \varepsilon^m_{k_m}) + \mu(p, \varepsilon^c_{k_c}) u^f(x^f, \varepsilon^f_{k_f})$. Consequently, without losing any important information, we map infinite dimensional unobserved heterogeneity into a finite-dimensional collection of graphs representing all possible revealed preference relations R^f, R^m and R^c.[6] We can directly identify them from data by making the following standard assumption (Cherchye, De Rock & Vermeulen, 2007, 2011):

Assumption 2. *(i) Unobserved preferences and distribution factors are constant over time, so that* $\varepsilon^r_i = \varepsilon^r_{i,t}$ *for all* $r \in \{f, m, \mu\}$, $t \in I_T$ *and* $i \in I_N$.

(ii) We observe choices for each household (couples and singles) for at least three periods.

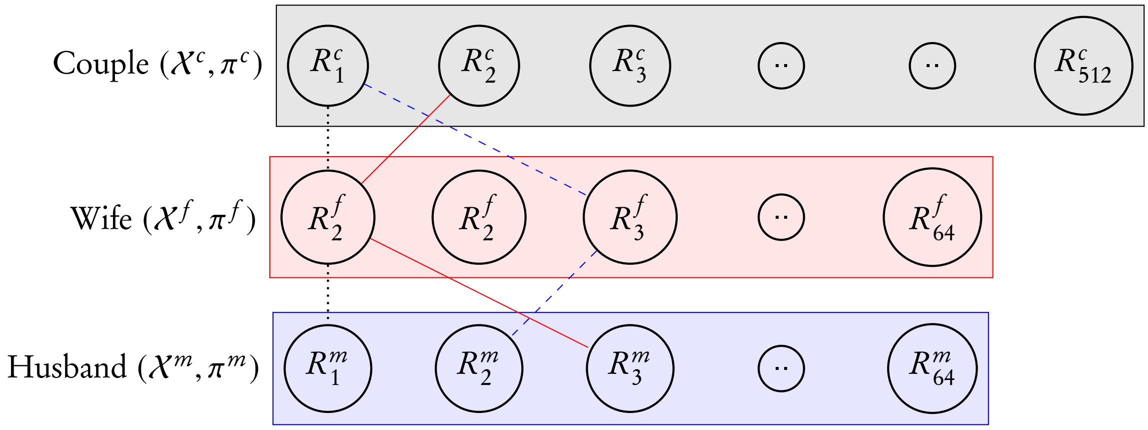
The time-homogeneity assumption of preferences is needed so that we can treat different periods as different price regimes. To be more precise, we have to assume that preferences do not change over time, such that we can treat the heterogeneity of choices between periods $t \in I_T$ as a consequence of individuals facing different prices p_t, rather than a change in preferences over time. Again, we discuss several possible extensions and ways to substitute this assumpion by different ones in Section 5.

Let $R^f, R^m \in \mathcal{X}^m = \mathcal{X}^f$ and $R^c \in \mathcal{X}^c$. While, the construction of the type space $\mathcal{X}^f$ is straightforward, constructing $\mathcal{X}^c$ requires an extension of the space of goods.[7] Considering a finite number of choice types allows us to fully characterise hypothetically matched households, by considering the product space $\mathfrak{X} = \mathcal{X}^c \times \mathcal{X}^f \times \mathcal{X}^m$. This should be interpreted as matching different consumption types $R^f(\varepsilon^f)$ and $R^m(\varepsilon^m)$ into different types of bargaining agreements $R^c(\varepsilon^c)$. Under the preference stability assumption, which ensures that single male and single female households are informative for the respective spouse's behaviour within a couple, each match,

[6]We use $R^c = R^c_0$ as notation. It does not actually represent a preference relation, since household consumption is only a result of individual preferences.

[7]This is due to the requirement of embedding information about double sums to evaluate CARP restrictions (iv) & (v) in Definition 1 of Appendix A.1. A discussion of the construction of type spaces for a minimal economy can be found in Appendix A.3.

Figure 1: Visualisation: Stochastic Collective Revealed Preferences



Note: 3-partite graph where the nodes represent discrete consumption decisions (revealed preference types) and the partitioning is such that there are three disjoint classes each representing the set of discrete decisions under a given household composition – single female f, single male m and couples and c. The marginal distributions π^c, π^f and π^m, supported on $\mathcal{X}^c$, $\mathcal{X}^f$ and $\mathcal{X}^m$, respectively, are identified from data. Edges between the type represent hypothetically matched households. Every possible match, represented by a tuple of edges, can be classified as rational or irrational according to a given set of restrictions.

characterised by the three-tuple (R^c, R^m, R^f), should behave rationally according to the collective model. Figure 1 presents a clustered graph representation of the type space for matched households. The edges between the nodes represent hypothetical matches and are *not* observed from data.

Thus, in a second step, we show that by using information about singles we can fully validate the revealed preference axioms for a heterogeneous population while only observing marginal distributions of choices for households with different compositions. To see this, let the probability that option $\xi_j \in \mathcal{X}^r$ is chosen by a household of a given composition r be denoted as $\pi(\xi_j|\mathcal{X}^r)$. By definition of our type space, this is equivalent to the probability of a household being of type R_j^r. We call this a stochastic choice in situation $\mathcal{X}^r$ and will often refer to it as the marginal distribution of choices under a given household composition. We can consistently estimate these distributions from sample frequencies. Using principles from stochastic choice theory (McFadden & Richter, 1991; McFadden, 2005), we can ask the question whether there exists a probability measure ν over an appropriate subset of matched household types $\mathfrak{X}^0 \subset \mathfrak{X}$ that rationalises the observed stochastic choices $\pi(\xi_j|\mathcal{X}^r)$

for $r \in \{c, f, m\}$. With this construction, the choice function $\mathcal{X} \mapsto \Xi(\mathcal{X})$, determining a decision rule for a given state of the world, is a function of household composition $\mathcal{X} \in \left\{\mathcal{X}^c, \mathcal{X}^f, \mathcal{X}^m\right\}$. We say that the stochastic choice π is stochastically rational if, for all household compositions $\mathcal{X}^r$ for $r \in \{c, f, m\}$, it holds that $\pi(\xi_j|\mathcal{X}^r) = \nu(\{\Xi \in \mathfrak{X}^0 : \xi_j = \Xi(\mathcal{X}^r)\}$ for some probability measure ν. Intuitively, if the choices in different states of the world (hypothetical matches) can be rationalised by a probability distribution over a set of rational matched household types (edges consistent with Ξ), we can say that the population is rational with respect to the decision rule Ξ.

Finally, how can we test the preference stability assumption by choosing the appropriate decision rule? For this, we partition the universe of types $\mathfrak{X} = \mathfrak{X}^{\text{collective}} \cup \mathfrak{X}^{\text{alternative}}$, where the set $\mathfrak{X}^{\text{collective}}$ contains all types of couples R^c for which there exists a tuple (H^f, H^m), which is consistent with the collective axiom as in Cherchye, De Rock & Vermeulen (2007, 2011). In order to use the actual respective preference relations (R^f, R^m) for a given matched household type, we require the preference stability assumption. We denote the subset of households who remain consistent with the collective axiom after replacing (H^f, H^m) by (R^f, R^m) as $\mathfrak{X}^0 = \mathfrak{X}^{\text{collective}} \setminus \mathfrak{X}^1$. Its complement $\mathfrak{X}^1$ then consists of the cases which satisfy the collective axiom based on couples data but are not consistent with the collective axiom if preference relations from singles are added. Thus, for our test, we drop all cases that are not collectively rational and test $\mathfrak{X}^0$ against $\mathfrak{X}^1$ to answer the question whether the stable preference hypothesis holds.[8] If we find that among the collectively rational couples it is not possible to rationalise observed choice probabilities using the types belonging to the set $\mathfrak{X}^0$, then we can conclude that the hypothesis of stable preferences does not hold.

[8]Alternatively, one could test $\mathfrak{X}^{\text{collective}}$ against $\mathfrak{X}^{\text{alternative}}$. In fact, this is what Cherchye, De Rock & Vermeulen (2007) do which does not require single data since such a test can be based on aggregate consumption only and the whole joint distribution of such choices is directly identified from data. Equally, by adding single data and assuming separable and stable preferences one could test $\mathfrak{X}^0$ against $\mathfrak{X}^1 \cup \mathfrak{X}^{\text{alternative}}$ to obtain a stronger test of the collective model compared to the previous one. While this test has more power, it comes with the drawback of only applying to a separable caring-type model.

3 Test Statistic

To construct a test statistic, it will be useful to represent the abstract choice rule Ξ, as something more traceable. McFadden & Richter (1991); McFadden (2005) show that stochastic choices can be represented by a linear system of equations $A\nu = \pi$. Lemma 1 summarises and extends some of these results.

Lemma 1. *The following statements are equivalent:*

(i) The population defined by choice distribution π and choice rules belonging to $\mathfrak{X}^0$ according to the random collective utility model (4) *is rational and satisfies the stable preference assumption.*

(ii) There exists $\nu \in \Delta^{|\mathfrak{X}^0|}$ such that $A\nu = \pi$ where Δ^M is the M-dimensional probability simplex and where the columns of A represent an exhaustive list of rational types according to (4) *under the preference stability assumption.*

(iii) Let $\underline{\nu} = 0$. Then the vector ν solves $\mathcal{J}_N(\pi, \underline{\nu}) := N \min_{\eta \in \{A\nu | \nu \geq \underline{\nu}\}} (\pi - \eta)^T \Omega (\pi - \eta) = 0$ where Ω is a positive definite square weighting matrix.

(iv) Similarly, for $\underline{\nu} = 0$ the vector ν is a fixed point under the operation

$$\Psi_{\pi,\underline{\nu}} : s \mapsto max(0, s - diag(H\iota)^{-1}(H^T s + f(\pi, \underline{\nu})) \tag{2}$$

where $H = A^T \Omega A$ and $f(\pi, \underline{\nu}) = -A^T \Omega(\pi - A\underline{\nu})$.

Proof. See Appendix A.2 □

A typical column of the matrix A is a hypothetically matched coherent couple, i.e. it stacks a male type (R^m), a female type (R^f), and a couple type (R^c) each individually rational, but also mutually coherent. In order to construct the matrix, we consider a matrix with $\sum_{r \in \{c,f,m\}} |\mathcal{X}^r|$ rows and $|\mathfrak{X}^0|$ columns, where $|\mathcal{X}^r|$ is the number of choices a household can make under a given composition. We then split all columns $A_{\bullet,k}$ with $k \in I_{|\mathfrak{X}^0|}$ into 3 blocks of respective length $|\mathcal{X}^c|$, $|\mathcal{X}^f|$ and $|\mathcal{X}^m|$ and denote each block by $A_{r,\bullet,k}$. If household match $k \in I_{|\mathfrak{X}^0|}$ is of type j under composition $r \in \{c, f, m\}$ then $A_{r,j,k} = 1$ and zero otherwise. In the graph interpretation of the type space in Figure 1, a block refers to a cluster of the graph and a match is represented by a column of the matrix A, where a row value of 1 indicates the active node.

Similarly, we obtain choice probabilities π by consistently estimating the empirical distribution of finite-dimensional household types from the continuous distribution of consumption for each household $i \in I_N$ and $r \in \{c, f, m\}$. Let π be a vector with $\sum_{r\in\{c,f,m\}} |\mathcal{X}^r|$ rows representing observed choice probabilities. Partitioning π the same way as a column A_k, for $r \in \{c, f, m\}$ we define $\pi_{r,j} = \frac{1}{N_r}\sum_{i\in I_{N_r}}\sum_{R^r\in\mathcal{X}^r} \mathbb{1}\{R_i^r = R^r\}$ where R_i^r is the type (preference relation) of household $i \in I_{N_r}$ and our sample is partitioned as $I_N = I_{N_c} \cup I_{N_f} \cup I_{N_m}$.

The way the matrix A is constructed, ν is not point-identified in $A\nu = \pi$ since A is far from full column rank with $|\mathfrak{X}^0| \gg \sum_{r\in\{c,f,m\}} |\mathcal{X}^r|$. Thus we make use of the equivalence between (ii) and (iii) in Lemma 1 and estimate η by projecting observed choice probabilities $\widehat{\pi}$ onto a τ_N-tightened[9] linear cone $C = \{A\nu : \nu \geq \tau_N\iota\}$ by minimising the projection residuals $\mathcal{J}_N(\widehat{\pi}, \iota\tau_N)$. We set $\tau_N = \frac{1}{H}\sqrt{\frac{\log \underline{N}}{\underline{N}}}$ where $\underline{N} = N_{\mathrm{f}} \wedge N_{\mathrm{m}} \wedge N_{\mathrm{c}}$ is the minimum number of available observations per household composition N_r for $r \in \{c, f, m\}$ in the sample.[10] To obtain the critical value, we then use a non-parametric bootstrap to obtain $\widehat{\pi}^b$ and calculate $\mathcal{J}_N\left(\widehat{\pi}^b, \iota\tau_N\right)$ for each $b \in I_B$, where B the number of bootstrap repetitions. Let $\widehat{\eta}_{\tau_N}$ be the argument producing the projection residuals $\mathcal{J}_N(\widehat{\pi}, \iota\tau_N)$. The centred choice probabilities $\widehat{\pi}^b_{\tau_N} = \widehat{\pi}^b - \widehat{\pi} - \widehat{\eta}_{\tau_N}$ are then used to approximate the empirical distribution $F_{\mathcal{J}_N}$ of $\mathcal{J}_N(\widehat{\pi}, \iota\tau_N)$. Then, following Kitamura & Stoye (2018), the bootstrap is valid and we have for $\alpha \in (0, \frac{1}{2})$ and $\tau_N\sqrt{N} \to \infty$

$$\lim \inf_{N\to\infty} \inf_{\pi\in C} \boldsymbol{P}\left(\mathcal{J}_N(\widehat{\pi}, \tau_N\iota) \leq \widehat{F^{-1}_{\mathcal{J}_N}}(1-\alpha)\right) = 1-\alpha. \tag{3}$$

The projection residuals are calculated for each bootstrap repetition and it will prove useful to rewrite Lemma 1.(iii) as the solution of a non-negative least squares problem and implement a fast algorithm for solving it. The most commonly used method to solve this is sequential quadratic programming, c.f. Lawson & Hanson (1995).[11] Due to the high dimensionality of our problem, it is preferable to use coordinate-wise projection such as in Franc, Hlavac & Navara (2005) or Landweber's gradient descent method (Johansson *et al.*, 2006) approach as it requires only $O(k)$ computations instead of $O(k^3)$, where $k = |\mathfrak{X}^0|$ is the (generally very large) number

[9]The tightening parameter τ_N is calibrated based on the results of our simulation study. The reason we require this feature is that many of the inequality constraints describing the cone are binding. With the parameter being on the boundary of the parameter space the bootstrap procedure we use would not be valid; Andrews (2000).

[10]The calibration of this parameter withstands different experiments performed as part of the Monte Carlo study in Appendix A.4.

[11]This algorithm is used for `lsqnonneg` in Matlab and `optimize.nnls` in SciPy.

of rational types in the NNLS problem. Equation (2) in Lemma 1.(iv) represents a step using Landweber's method, which we implement from first principles, in order to leverage the sparsity of the matrix A.

Appendix A.4 discusses the results of a simulation study in which we evaluate the power of our test by plotting empirical rejection frequencies against the proportion of households not optimising according to a given decision rule and its size by evaluating type 1 errors under worst case scenarios. We find that the test has power to detect an "irrational" population of close to one with 500 observations per household composition if only 15% of the sample do not behave according to the model. If the sample size is doubled, the required proportion drops to 5%. In addition to this, we discuss worst cases by considering "similar matches" and show that the size of the test is correct under different worst-case samples.

4 Results

In this section, we apply our test to three different datasets. Two of them are widely used in our context: The Russian Longitudinal Monitoring Survey (RLMS) and the Spanish Continuous Family Expenditure Survey (ECPF). Neither of these datasets have information about allocation of consumption between the spouses. We complement this by also applying the test to the Longitudinal Internet Studies for the Social Sciences (LISS), a higher quality dataset which includes more information than required. The results are consistent between the three datasets. In all cases, we reject the hypothesis of stable preferences.

For the test we consider households consisting of singles or couples. We exclude households with children or other cohabiting groups of individuals who are not in a romantic relationship. We consider a minimal setting with three periods and three goods, where we have 64 types of singles and 512 types of couples, resulting in $2,996$ collectively rational matched household types who satisfy the stable preference assumption.[12] Two of the panels we study are longer than required. Consequently, we evaluate different combinations of years and goods from a range of pre–defined private

[12]See Appendix A.3 for a detailed discussion of this setting.

goods.[13] After dropping incomplete and boundary cases, we select years and goods based on the resulting sample size. Due to attrition in panels, this procedure tends to pick out consecutive years. As such, we face the trade–off between a small sample size and small price variation, where the latter decreases the power in any revealed preference setting (see e.g. Beatty & Crawford, 2011). Thus, in addition to the combination with the largest sample size, we report a range of such combinations for a fixed group of goods, in descending order of $N_{\text{couples}} + N_{\text{singles}}$.

First, we apply our test to the time use and consumption module (Cherchye, De Rock & Vermeulen, 2012b) from the Dutch LISS (Longitudinal Internet Studies for the Social Sciences) panel. This longitudinal study is collected by CentERdata and consists of 5000 households and 8000 individuals, which are drawn from the population register of Statistics Netherlands. The survey is internet-based where households are provided with the necessary hardware to participate in the study. Prices are obtained from the Dutch CPI for different consumption categories published by Eurostat (normalized to 100 for the year 2005). We select the private consumption categories: clothing, food & beverages and recreation.

Second, we consider phase two of the Russian Longitudinal Monitoring Survey (RLMS), collected in form of a personal interview by the Carolina Population Center (University of North Carolina) and available for the years 1994 – 2014. Due to a lot of missing or zero values of other types of private consumption expenditures, we focus on different categories of food.[14] The survey distinguishes between 57 different food consumption categories, which we further aggregate to dairy, bread and meat. These three categories account for more than half of the food consumption. Price data is obtained from the Federal State Statistics Service (GKS) and available for the years: 2000, 2005, 2010, 2011 – 2015.

Third, to validate the results above, we apply the test to data from the Spanish Continuous Family Expenditure Survey (ECPF), collected by the Spanish statistics office (INE) on a quarterly basis for the period 1985 – 2005. The survey is designed in a way that participants are part of the sample for at most eight consecutive periods or two years. There was a discontinuity in the design of the study in 1997, where

[13] We make use of a weak separability assumption that is standard in the empirical demand estimation literature which allows us to be able to consider a subset of goods for estimation.

[14] The median household income is RUB $28,000$, of which RUB $7,500$ is spent on food.

the focus was shifted away from detailed consumption expenditure categories. While the ECPF was replaced by the Encuesta de Presupuestos Familiare (EPF) in 2006, unfortunately the collection frequency of this newer version was extended to once per year while the participation lifespan of two years was maintained. Requiring a panel of at least three periods we, therefore, use data from the original ECPF from 1985 to 1996. Similar to the LISS panel, we select the following private goods: clothing, food consumed outside of the household and consumption of non–durable articles. Price data is also published by INE. Descriptive statistics of all datasets can be found in Table 7 in Appendix A.5. Table 1 and Table 2 present the results in the form of p-values for different combinations of periods with and without covariates, respectively.

Two aspects of our results are worth noting. First, while there is overwhelming evidence to reject the stable–preference hypothesis for the RLMS, there are some combination of periods for which there is not enough evidence to arrive at this conclusion. In any of these cases, we either have three consecutive years in which we are faced with little power of revealed preference axioms due to the lack of price variation, or a particularly small sample size due to the wider span of considered years in combination with (random) attrition. This all points towards the trade–off discussed above. Second, our sample for the ECPF is very small, particularly for single households. Abstracting from the inferior statistical properties of the test in small samples (the numerical procedure still converges), the strong rejection of the hypothesis seems to indicate that it is harder to find a rationalisation of types when we observe zero probability mass for some types $R \in \mathcal{X}^r$ for some $r \in \{c, f, m\}$.

5 Extensions

In this section we discuss extensions regarding the two main assumptions made in this paper: no consumption externalities, and time stability of preferences. However, it should be noted that identification under these extensions comes at the expense of loosing general preference heterogeneity.

To account for arbitrary consumption externalities, let us augment our random utility model by implementing a linear consumption technology (Barten, 1964; Browning, Chiappori & Lewbel, 2013). The household then maximises the consumption problem

$$\max_{x^f, x^m} \left\{ u^m(x^m, x^f, \varepsilon^m) + \mu(p, \varepsilon^\mu) u^f(x^f, x^m, \varepsilon^f) \right\} \tag{4}$$
$$\text{s.t. } z \in B_t = \left\{ x \mid p_t x \leq w_t \right\}$$
$$z = A(x^f + x^m),$$

where A is a diagonal matrix with elements ranging from 0.5 (entirely public good) to 1.0 (entirely private good). The production technology matrix A is not identified in the context of arbitrary unobserved heterogeneity such as our revealed preference setting. Thus we will impose estimates from (Cherchye *et al.*, 2017), a study conducted using the LISS panel, one of the datasets used in this paper. This restricts us to use public goods from the intersection of their study and the datasets we consider. Our choice of public goods is: housing, transport and energy, with the following Barten scales:

$$A = \begin{bmatrix} 0.683 & 0 & 0 \\ 0 & 0.692 & 0 \\ 0 & 0 & 0.748 \end{bmatrix}.$$

They, arguably, represent goods subject to consumption externalities taking values about half way on the spectrum from public to private. While the specifications for the RLMS and LISS contain only public goods, this approach allows for arbitrary combinations of public and private goods by setting $A_{ii} = 1$ for purely private goods $i \in I_L$. Because the ECPF only has different forms of transportation and no information on housing and energy consumption, for this dataset we use clothing, transportation and petrol. We obtain secondary house price indices (HPI) from the same sources as the respective consumer price indices (CPI). Table 3 and 4 present the results, respectively, confirming the evidence we find in the context of private goods.

Regarding time stability of preferences, there are a range of possible approaches, all of which come at the expense of requiring additional strong and non-testable assumptions. First, it is possible to extend the type space as follows. Keeping the number of total types $\mathfrak{X}$ unchanged we could extend the space of marginal choices $\mathcal{X}^r$ to the product space over both household composition and time: $r \in \{f, m, c\} \times \{1, 2, 3\}$. For couples this additionally requires encoding the product space of possible subregions of the budget planes relevant to form equivalence classes for the involved double sums. The latter comes with the caveat that it requires a homotheticity assumption instead of the time-stability assumption. Such a setting would also eliminate all the power of the collective axiom of revealed preference, making this a test of collective bargaining rather than preference stability. Second, one could make use of a structural assumption on the utility functions in order to obtain continuous demands of the form $x_{it} = x(p_t, \varepsilon_i) + \varepsilon_{it}$, where ε_i is an element of a general probability space capturing unobserved heterogeneity and ε_{it} is a period specific idiosyncratic taste shock. Identification of such a specification is treated in Evdokimov (2010). In such a setting, we would not only lose a lot of identifying variation in prices, but also the advantage of not having to project observed demands onto budget sets to reduce the dimension of the choice space, such as Kitamura & Stoye (2018), which again requires a homotheticity assumption or a revealed price preference setting; c.f. Deb *et al.* (2017). Finally, one could resort to a different set of revealed preference axioms, such as marriage market matching (Cherchye *et al.*, 2017). Again, this would only substitute the joint restriction tested with a different one, in the matching case the so-called non-blocking pairs assumption.

6 Conclusion

In this paper, we proposed a way to incorporate singles for identification in a non-parametric collective revealed preference setting and used it to construct a test for the hypothesis of stable preferences. For this, we set up a collective random utility model and a unitary random utility model and used a discretisation of continuous choices to revealed preference types for both types of households. We then asked the question under which conditions we can construct hypothetical matches of different heterogeneous individuals into different types of households. In a caring model, this is possible under the assumption of stable preferences, which formed the basis for our test. By considering collectively rational couples and a stochastic choice argument, we then showed that under the null hypothesis of stable preferences, there exists a stochastic rationalisation of observed choice data. Using data from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS), the Russian Longitudinal Monitoring Survey (RLMS), and the Spanish Continuous Family Expenditure Survey (ECPF) we strongly rejected the hypothesis.

References

Abi Adams, Laurens Cherchye, Bram De Rock & Ewout Verriest (2014), Consume now or later? Time inconsistency, collective choice, and revealed preference. *American Economic Review*, vol. 104, no. 12, pp. 4027–4070.

Sydney Afriat (1967), The construction of utility functions from expenditure data. *International Economic Review*, vol. 8, no. 1, pp. 67–77.

Donald Andrews (2000), Inconsistency of the Bootstrap when a Parameter is on the Boundary of the Parameter Space. *Econometrica*, vol. 68, no. 2, pp. 399–405.

James Banks, Richard Blundell & Arthur Lewbel (1997), Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics*, vol. 79, no. 4, pp. 527–539.

Anton Peter Barten (1964), Family composition, prices and expenditure patterns. Netherland ed., Netherlands School of Economics.

Timothy Beatty & Ian Crawford (2011), How demanding is the revealed preference approach to demand? *American Economic Review*, vol. 101, no. 6, pp. 2782–2795.

Gary S. Becker (1981), Altruism in the Family and Selfishness in the Market Place. *Economica*, vol. 48, no. 189, pp. 1–15.

Martin Browning & Pierre-Andre Chiappori (1998), Efficient Intra-Household Allocations: A General Characterization and Empirical Tests. *Econometrica*, vol. 66, no. 6, pp. 1241–1278.

Martin Browning, Pierre-Andre Chiappori & Arthur Lewbel (2013), Estimating consumption economies of scale, adult equivalence scales, and household bargaining power. *Review of Economic Studies*, vol. 80, no. 4, pp. 1267–1303.

James Brugler (2016), Testing preference stability between couples and singles. *Economics Letters*, vol. 142, pp. 15–17.

Laurens Cherchye, Bram De Rock & Frederic Vermeulen (2007), The collective model of household consumption: a nonparametric characterization. *Econometrica*, vol. 75, no. 2, pp. 553–574.

Laurens Cherchye, Bram De Rock & Frederic Vermeulen (2009), Opening the black box of intra-household decision-making. *Journal of Political Economy*, vol. 117, no. 6, pp. 1074–1104.

Laurens Cherchye, Bram De Rock & Frederic Vermeulen (2011), The Revealed Preference Approach to Collective Consumption Behaviour: Testing and Sharing Rule Recovery. *The Review of Economic Studies*, vol. 78, no. 1, pp. 176–198.

Laurens Cherchye, Bram De Rock & Frederic Vermeulen (2012a), Economic well-being and poverty among the elderly: An analysis based on a collective consumption model. *European Economic Review*, vol. 56, no. 6, pp. 985–1000.

Laurens Cherchye, Bram De Rock & Frederic Vermeulen (2012b), Married with children: A collective labor supply model with detailed time use and intrahousehold expenditure information. *American Economic Review*, vol. 102, no. 7, pp. 3377–3405.

Laurens Cherchye, Thomas Demuynck, Bram De Rock & Frederic Vermeulen (2017), Household consumption when the marriage Is stable. *American Economic Review*, vol. 107, no. 6, pp. 1507–1534.

Pierre-Andre Chiappori (1988), Rational household labor supply. *Econometrica*, vol. 56, no. 1, pp. 63–90.

Pierre-Andre Chiappori (1992), Collective labor supply and welfare. *Journal of Political Economy*, vol. 100, no. 3, pp. 437–467.

Pierre André Chiappori, Robert J. McCann & Lars P. Nesheim (2009), Hedonic price equilibria, stable matching, and optimal transport: Equivalence, topology, and uniqueness. *Economic Theory*, vol. 42, no. 2, pp. 317–354.

Rahul Deb, Yuichi Kitamura, John K.H. Quah & Jörg Stoye (2017), Revealed Price Preference: Theory and Empirical Analysis. *Cowles Foundation Discussion Paper*, vol. 1, no. 2087, pp. 1–22.

Holger Dette, Stefan Hoderlein & Natalie Neumeyer (2016), Testing multivariate economic restrictions using quantiles: the example of Slutsky negative semidefiniteness. *Journal of Econometrics*, vol. 191, no. 1, pp. 129–144.

Kirill Evdokimov (2010), Identication and Estimation of a Nonparametric Panel Data Model with Unobserved Heterogeneity. *Unpublished Manuscript: Princeton University*, pp. 1–62.

Vojtech Franc, Vaclav Hlavac & Mirko Navara (2005), Sequential coordinate-wise algorithm for the non-negative least squares problem. *Computer Analysis of Images and Patterns*, vol. 3691, pp. 407–414.

George-Levi Gayle & Andrew Shephard (2019), Optimal Taxation, Marriage, Home Production, and Family Labour Supply. *Econometrica*, vol. 87, no. 1, pp. 291–326.

Stefan Hoderlein & Jörg Stoye (2014), Revealed preferences in a heterogeneous population. *Review of Economics and Statistics*, vol. 96, no. 2, pp. 197–213.

Stefan Hubner (2018), Reacher or Settler? Unobserved Distribution Factors and Preferences in the Collective Household Model. *Unpublished Manuscript*.

Bjoern Johansson, Tommy Elfving, Vladimir Kozlov, Yair Censor, Per-Erik Forssen & Goesta Granlund (2006), The application of an oblique-projected Landweber method to a model of supervised learning. *Mathematical and Computer Modelling*, vol. 43, no. 7, pp. 892–909.

Yuichi Kitamura & Jörg Stoye (2018), Nonparametric Analysis of Random Utility Models: Testing. *Econometrica*, vol. 86, no. 6, pp. 1883–1909.

Charles L. Lawson & Richard J. Hanson (1995), Solving Least Squares Problems. In SIAM, classics i ed.

Arthur Lewbel & Krishna Pendakur (2008), Estimation of collective household models with Engel curves. *Journal of Econometrics*, vol. 147, no. 2, pp. 350–358.

Maurizio Mazzocco, Claudia Ruiz & Shintaro Yamaguchi (2014), Labor Supply and Household Dynamics. *American Economic Review*, vol. 104, no. 5.

Daniel McFadden (2005), Revealed stochastic preference: a synthesis. *Economic Theory*, vol. 26, pp. 245–264.

Daniel McFadden & Marcel Richter (1991), Stochastic rationality and revealed stochastic preference. In Preferences, Uncertainty, and Optimality (edited by J. Chipman, D. McFadden & M.K. Richter.), Boulder: Westview Press, pp. 161–186.

Hal Varian (1982), The nonparametric approach to demand analysis. *Econometrica*, vol. 50, no. 1, pp. 945–73.

Alessandra Voena (2015), Yours, mine, and ours: Do divorce laws affect the intertemporal behavior of married couples? *American Economic Review*, vol. 105, no. 8, pp. 2295–2332.

A.1 Collective Axiom of Revealed Preference

Definition 1 (Cherchye, De Rock & Vermeulen, 2007). *Suppose that there exists a pair of utility functions u^f and u^m that provide a collective rationalization of the set of observations $\left\{(p_t; \tilde{x}_t^c, \tilde{x}_t^f, \tilde{x}_t^m) : \tilde{x}_t^c = \tilde{x}_t^f + \tilde{x}_t^m, t \in I_T\right\}$. Then there exist preference relations*[15] *R_0^r and R^r for each $r \in \{c, m, f\}$ such that:*

(i) *if $\tilde{x}_s R_0^c \tilde{x}_t$, then $\tilde{x}_s R_0^f \tilde{x}_t$ or $\tilde{x}_s R_0^m \tilde{x}_t$*

(ii) *if $\tilde{x}_s R_0^r \tilde{x}_{s_1}$, $\tilde{x}_{s_1} R_0^r \tilde{x}_{s_2}, \ldots, \tilde{x}_{s_S} R_0^r \tilde{x}_t$ then $\tilde{x}_s R^r \tilde{x}_t$ for $r \in \{m, f\}$*

(iii) *if $\tilde{x}_s R_0^c \tilde{x}_t$ and $\tilde{x}_t R^r \tilde{x}_s$, then $\tilde{x}_s R_0^{r'} \tilde{x}_t$ for $r \neq r'$ where $r, r' \in \{m, f\}$*

(iv) *if $\tilde{x}_s R_0^c \left(\tilde{x}_{t_1} + \tilde{x}_{t_2}\right)$ and $\tilde{x}_{t_1} R^r \tilde{x}_s$ then $\tilde{x}_s R_0^{r'} \tilde{x}_{t_2}$ for $r \neq r'$ where $r, r' \in \{m, f\}$.*

(v) *if $\tilde{x}_{s_1} R^f \tilde{x}_t$ and $\tilde{x}_{s_2} R^m \tilde{x}_t$ then $\neg\left(\tilde{x}_t R_0^c \left(\tilde{x}_{s_1} + \tilde{x}_{s_2}\right)\right)$*

(vi) *if $\tilde{x}_s R^f \tilde{x}_t$ and $\tilde{x}_s R^m \tilde{x}_t$, then $\neg\left(\tilde{x}_t R_0^c \tilde{x}_s\right)$*

where R^r is defined as $\tilde{x}_s R_0^r \tilde{x}_t$ whenever $p_s \tilde{x}_s^r \geq p_s \tilde{x}_t^r$ and R^r is the transitive closure of R_0^r (Afriat, 1967; Varian, 1982).

[15] Note that R_0^c is just notation and not actually a preference relation, since household consumption is only a result of individual preferences.

A.2 Proofs

Proof of Lemma 1. The equivalences between (i), (ii) and (iii)' are shown in McFadden & Richter (1991); McFadden (2005). Statement (iii)' referenced therein, differs from (iii) in that it additionally requires $\iota^T \nu = 1$. We now show that this is implied. It is easy to see that by construction of A for any solution of the quadratic problem we have $\eta = \pi$ and since $3 = \iota^T \pi = \iota^T A\nu = 3\iota^T \nu$ by construction of the 3-petite graph, we get $\iota^T \nu = 1$. Thus constraint $\nu \geq 0$ in is sufficient for η to be on the probability simplex.

It will be useful to write this problem with a *tightened* cone constraint indexed by $\underline{\nu}$. Let L be a lower diagonal matrix from the Cholesky decomposition $\Omega = LL^T$. Then we can rewrite the quadratic form (iii) as

$$\min_{\eta \in \{A\nu | \nu \geq \underline{\nu}\}} (\pi - \eta)^T LL^T (\pi - \eta).$$

Using $\eta = A\nu$ and introducing a slack variable $s \geq 0$ such that we can write $\nu = \underline{\nu} + s$ we obtain

$$\min_{\nu = \underline{\nu} + s, s \geq 0} (\pi - A(\underline{\nu} + s))^T LL^T (\pi - A(\underline{\nu} + s)).$$

This does not depend on ν but only on s and we can write it in the quadratic form

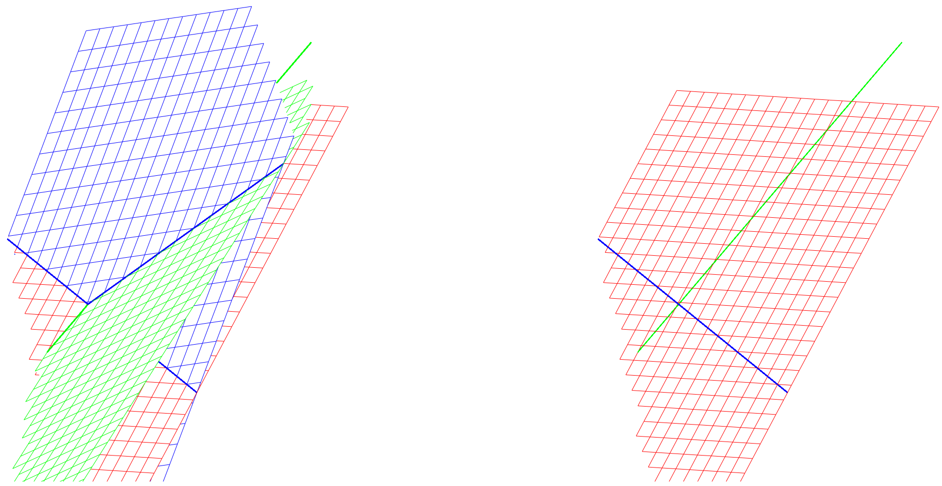
$$\min_{s \geq 0} \left\{ \frac{1}{2} s^T A^T \Omega A s - s^T A^T \Omega (\pi - A\underline{\nu}) \right\}.$$

Letting $H = A^T \Omega A$ and $f(\pi, \underline{\nu}) = -A^T \Omega (\pi - A\underline{\nu})$ we get a canonical form of a non-negative least squares problem, with gradient for iteration $\tau \geq 0$ defined as $\mu_\tau = H^T s_\tau + f(\pi, \underline{\nu})$. Johansson *et al.* (2006) show that component-wise projection $s_{\tau+1,j} = \max(0, s_{\tau,j} - \mu_{\tau,j} d_j)$ where $d = \text{diag}(H\iota)^{-1}$ and $j \in I^{|\mathfrak{X}^0|}$ referring to the j^{th} component of s will find the solution of the problem. □

A.3 A Minimal Example

To test the collective model using revealed preferences, at least three periods and three different goods are needed. This section discusses the strategy and dimensionality of our test in such a minimal setting.

Figure 2: Three intersecting budget sets $B_{\text{red}}, B_{\text{blue}}, B_{\text{green}}$ with three goods



Note: Example of a three-good economy with three price-regimes characterizing budgets B_t where $t \in \left\{\underline{\text{b}}\text{lue}, \underline{\text{r}}\text{ed}, \underline{\text{g}}\text{reen}\right\} = I_T$. In the figure on the right hand side the green and blue budgets are removed and only the lines in which they intersect with the remaining red budget are plotted.

We can make revealed preference statements whenever some bundle of goods was chosen, but a different less expensive one would have been affordable. In Figure 2, the colors of the budget sets are defined such that whenever a household chose one of the four regions on a budget set that was above another budget set, then the good corresponding to this color is revealed preferred to the good corresponding to the color of the other budget set. For example if a single female household picks one of the lower quadrants of the red budget such that $p_{\text{blue}} x_{\text{red}} \leq p_{\text{red}} x_{\text{red}}$, we can say that $x^{\text{red}}\ R^f\ x^{\text{blue}}$.

To clarify the construction of preference types from continuous data, we will now consider an example of a hypothetical household match, faced with the respective budgets. For this, assume we observe a single female consuming x_r^f, x_b^f and x_g^f, a single male consuming x_r^m, x_b^m and x_g^m and consider them to be matched into a couple of type equivalent to one consuming x_r^c, x_b^c and x_g^c. We normalize household endowment to one. Their consumption satisfies the following inequalities which contain all the necessary information to characterise the matched household in terms of preference relations which can be checked against the Collective Axiom of Revealed

Preference.

$$\begin{array}{c|c|c} p_b x^c_r \geq 1, \quad p_g x^c_r \geq 1, \quad p_r(x^c_b + x^c_g) \geq 1 & p_b x^m_r \leq 1, \quad p_g x^m_r \geq 1, & p_b x^f_r \geq 1, \quad p_g x^f_r \leq 1 \\ p_r x^c_b \geq 1, \quad p_g x^c_b \geq 1, \quad p_b(x^c_r + x^c_g) \geq 1 & p_r x^m_b \geq 1, \quad p_g x^m_b \leq 1, & p_r x^f_b \geq 1, \quad p_g x^f_b \geq 1 \\ p_r x^c_g \leq 1, \quad p_b x^c_g \geq 1, \quad p_g(x^c_r + x^c_b) \leq 1 & p_r x^m_g \geq 1, \quad p_b x^m_g \geq 1, & p_r x^f_g \geq 1, \quad p_b x^f_g \geq 1 \end{array}.$$

If f and m were to be matched together, the inequalities restricting x^c represent one potential joint consumption type, in which case the graphs of the respective preference relations are

$$R_0 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad R^m_0 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \qquad R^f_0 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

with transitive closures for both individuals:

$$R^m = \begin{bmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \qquad R^f = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

Table 5 shows different violations of the collective axiom. Situation (1) is a trivial violation of individual SARP by f. In the example above we have situation (2), in which the preference relation R^m_0 is one of a person who prefers good A over good B and good B over good C. Thus he must also prefer good A over good C by transitivity, for which there is no contradicting revelation of preferences. Hence, this person is rational. The preference relation of R^f_0 also represents a rational person, who prefers good A over good C. This implies that both individuals prefer good A over good C, but aggregate household consumption represented by R^c_0 revealed that the household chose good C over good A; a violation of the Collective Axiom of Revealed Preference. This households also violates type (3), in which it could have consumed both A and B, but chose to consume only C instead, making both individuals worse off.

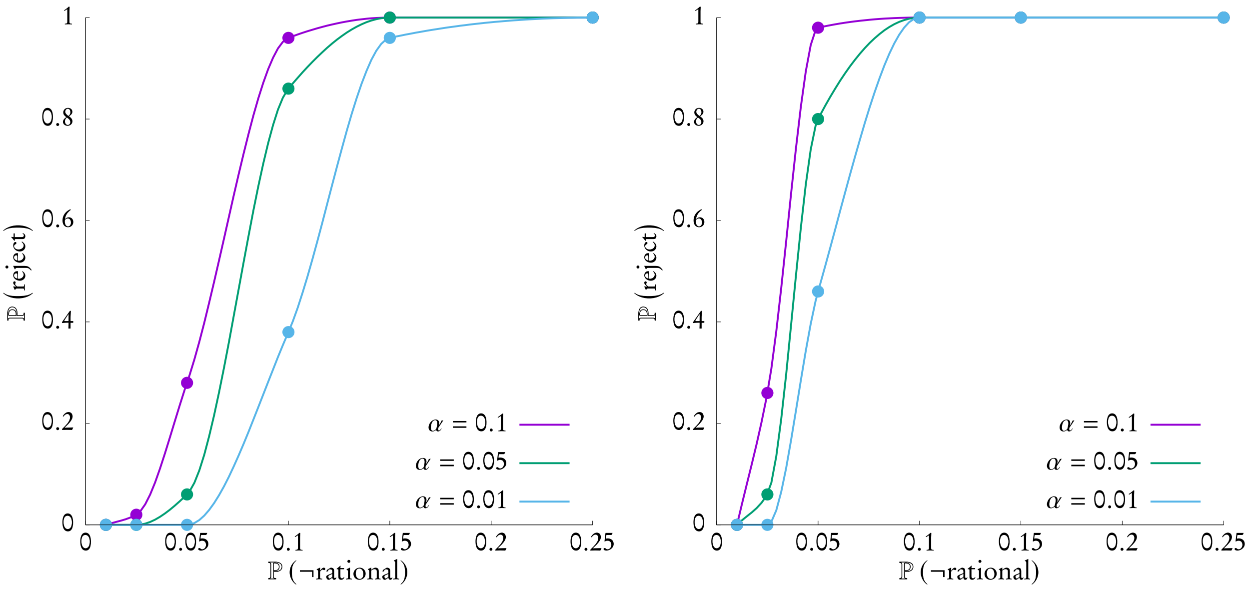
In our setting, the cardinality of $\mathcal{X}^r$ is $|\mathcal{X}^r| = 4^3 = 64$ for $r \in \{m, f\}$ representing single males and single females, respectively. For couples, we have to evaluate inequalities for double-sums according to Definition 1 (iv) & (v), for which we have 2^κ different possibilities with $\kappa = \frac{1}{2}T(T-1) = 3$ which results in $4^3 * 2^3 = 512$ choices. In total, we thus have $|\mathfrak{X}| = 512 * 64 * 64 = 2,097,152$ matched household types. Applying a revealed preference test for this universe of types and removing the ones that violate the collective axiom under the preference stability assumption, we end up with $|\mathfrak{X}^0| = 2,996$ matched household types. $|\mathfrak{X}^{\text{collective}}| = 475,136$ are consistent with the collective axiom based on the necessary conditions using only aggregate household consumption data. This leaves us with about 22.7% collectively rational types. From this, we should not necessarily conclude a restrictive nature of the collective model since for a given range of budget planes only a subset of the total choice set would actually be feasible (e.g. have positive demands). Hence we obtain a matrix A with $512 + 64 + 64 = 640$ rows and $2,996$ columns representing rational types under the stable preference assumption. The vector π is a vector of choice probabilities of the population of the same dimension: 640. The matrix is sparse and only has $3|\mathfrak{X}^0| = 3 * 2,996$ non-zero items.

A.4 Simulations

In this section, we investigate the properties of our proposed test in a simulation setting. In particular, we are interested in how much power it has to detect a violation of the stable preference assumption and whether or not it has a correct proportion of false positives. Since specifying a parametric continuous demand system requires at least five goods to impose the SNR(S-1) condition on the Slutsky matrix and distinguish the collective model from the unitary model, we will not sample continuous demands as functions of prices and individual budget constraints, but rather draw our sample directly from the discrete choice space.[16] This should be interpreted as a continuous uniform distribution of choices on different budget planes, where the relative prices are such that the partitions of the budget planes are of equal size. Recall that we test this against the set of households which are consistent with the necessary conditions of the collective axioms based on aggregate consumption but not consistent when single data and the stable preference assumption is added. This set is denoted by $\mathfrak{X}^1$ and we have $\mathfrak{X}^{\text{collective}} = \mathfrak{X}^0 \cup \mathfrak{X}^1$. If we reject the null hypothesis that both the collective axiom and the stable preference assumption holds, by excluding all irrational matches $\mathfrak{X} \setminus \mathfrak{X}^{\text{collective}}$, we must conclude that the stable preference assumption does not hold. To control the proportion of households for whom this is the case (our

[16] A revealed preference based setting allows us to test the restrictions of the model with only three goods (Cherchye, De Rock & Vermeulen, 2007), whereas Browning & Chiappori (1998) need five goods.

Figure 3: Power function for $N = 1,500$ (l.h.s) and $N = 3,000$ (r.h.s.)



data generating process) we introduce the parameter p which specifies the probability that a particular choice is both collectively rational and satisfies the stable preference assumption $p := \boldsymbol{P}(x \in \mathfrak{X}^0)$.[17] By only considering collectively rational choices in our simulations we thus have $1 - p = \boldsymbol{P}(x \notin \mathfrak{X}^0) = \boldsymbol{P}(x \in \mathfrak{X}^1)$ by construction.

Our simulation setting is as follows. We consider $S = 100$ samples of size $\underline{N} \in \{500, 1000, 2000\}$ where $\underline{N} = N_f = N_m = N_c$ such that $N = 3\underline{N}$ in a minimal setting with $T = 3$ periods which we construct by drawing $\lfloor \underline{N}p \rfloor$ indices from the space of collectively rational matches $\mathfrak{X}^0$ for which the stable preference assumption holds and $\lceil \underline{N}(1-p) \rceil$ indices from the space of collectively rational types $\mathfrak{X}^1$ which does not satisfy the assumption. Based on a sample of matches, we then calculate the choice probabilities $\widehat{\pi}$ accordingly. For estimation, we only use the marginal distribution of choices of each sample of household compositions and draw $B = 100$ samples from the respective empirical distributions (i.e. with replacement) to calculate $\pi^b_{\tau_N}$ and estimate the empirical distribution of the test statistic $\mathcal{J}^{\tau_N}_{N,b}$. These simulations are repeated for $p \in \{0.75, 0.85, 0.9, 0.95, 0.975, 0.99, 1.00\}$.

Figure 3 shows the power of our test against the non-stable preference alternative as a function of p, with sample-size $\underline{N} = 500$ for the left-hand side graph, and $\underline{N} = 1000$ for the right-hand side graph, respectively. We use monotone cubic splines to

[17]This rationality parameter is similar as for example λ in Dette, Hoderlein & Neumeyer (2016) which specifies the population's deviation from Slutsky symmetry.

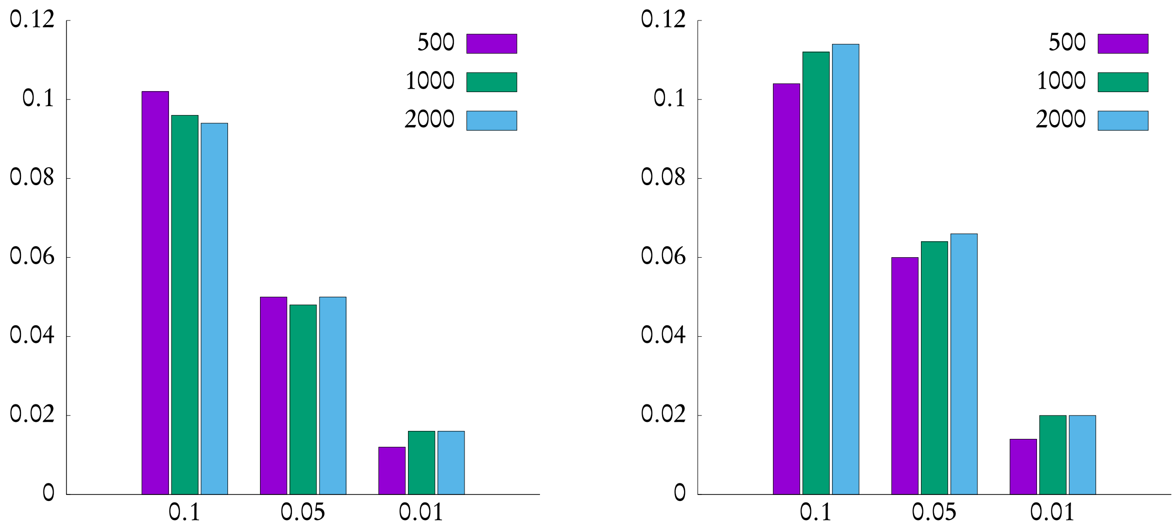
interpolate between the actual simulation results, which are marked as solid dots. To be more precise, the respective functions refer to sample rejection frequencies using the rejection rule $J \mapsto \mathbb{1}\left\{J > \widehat{F^{-1}_{\mathcal{J}_N}}(1-\alpha)\right\}$ for $\alpha \in \{0.01, 0.05, 0.10\}$. In addition to this, we also observe that as $\underline{N}$ increases the power of our test improves and is able to correctly reject the hypothesis of a collectively rational population already at small proportions p.

The intercepts of these functions should be interpreted as the proportion of false positives (type I errors) since they correspond to the case where everyone is rational. One might expect that for a correctly sized test the empirical rejection frequencies should tend to α. However, given our partial identification procedure we have a composite null hypothesis, *i.e.* the probability of a type I error should be at most α as defined in equation (3). To see this note that every vector of "true" choice frequencies denoted by π_0 lying in the interior of the cone will have projection residuals of length zero. Bootstrapping out of $\widehat{\pi}$ which tends to π_0 using the usual regularity properties could then lead to a confidence interval which is always entirely in the interior of the cone and we would never wrongly reject the null hypothesis. This also implies that in such a case our bootstrap distribution is degenerate and has mass one at point zero.

In our Monte Carlo setting and the case where $p = 1.0$, we randomly select types from the type-space $\mathfrak{X}^0$, satisfying collective rationality. Thus the "true" parameter vector ν_0 is assumed to have a uniform distribution over the probability simplex and the worst-case, namely to get a ν such that $\pi_0 = A\nu$ is on the boundary of the cone with respect to any of its dimensions, occurs with measure zero.

Thus, in order to evaluate whether the size of our test is correct under the test's minimax strategy, we have to construct a worst case. For this, note that the test is constructed in a way that considers hypothetical types by taking combinations of possible household choice behaviour per price regime over a range of price regimes. To fix notation, we will call two collectively rational matches *similar* if there is at least one element in the product space spanned by these two matches which is an element of the space of collectively rational matches that do not satisfy the stable preference hypothesis. We will then construct worst cases by specifying a distribution over n_0 such similar matches. To make sure that our π_0 is on the boundary of the cone in all dimensions, *i.e.* on the cusp, we shift the cone by manually controlling the tightening

Figure 4: Type I error for $n_0 = 5$ (l.h.s) and $n_0 = 2$ (r.h.s.) worst-case matches



parameter τ_N according to this distribution. Figure 4 shows simulation results for two such worst case scenarios with 5 similar matches and 2 similar matches, respectively.

The size results do not seem to deteriorate much with the number of worst case matches included in the sample. Since the properties of the test are based on an asymptotic argument, we should see the empirical frequency of false positives tending to the respective α which define the rejection rules and are plotted on the x-axis. The results are what one would expect, with all sample sizes being reasonably accurate. Since in a well-behaved test, false-positives are by definition rather rare events, in order to minimize simulation uncertainty, we increased the number of Monte Carlo repetitions to $S = 500$ and the number of bootstrap repetitions to $B = 200$, which greatly increased computational complexity due to the high dimensionality of the testing problem.

A.5 Descriptive Statistics

Table 6: Descriptive Statistics (Private Goods)

Longitudinal Internet Studies for the Social Sciences (LISS)										
			Food out			Clothing			Leisure	
Year	N	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
2009	5594	43.463	45.0	108.1	69.825	60.0	107.4	20.121	20.0	98.6
2010	5337	38.798	50.0	109.7	71.835	75.0	105.3	23.362	20.0	98.0
2012	5463	40.611	50.0	113.4	74.347	80.0	106.6	23.743	25.0	100.4
Russian Longitudinal Monitoring Survey (RMLS)										
			Dairy			Bread			Meat	
Year	N	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
2000	1506	81.7	120.4	121.1	113.2	102.8	116.5	322.0	439.7	128.3
2005	1601	222.3	277.8	110.5	199.3	171.8	103.0	1003.5	1175.8	118.6
2010	2839	475.7	492.7	116.7	303.3	270.8	107.6	1862.1	1926.0	105.3
2011	2983	520.3	544.8	106.3	317.3	270.9	108.9	2165.8	2154.7	109.2
2012	3154	551.0	550.5	104.4	330.2	291.7	112.0	2284.8	2315.0	108.3
2013	3076	617.7	622.9	113.1	352.9	287.1	108.0	2366.2	2399.8	97.0
2014	2516	695.3	675.8	114.4	372.9	323.0	107.5	2805.6	2847.5	102.1
Spanish Continuous Family Expenditure Survey (ECPF)										
			Clothing			Food out			Nondurables	
Year	N	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
1985	65	1284.4	1406.4	165.7	940.9	899.7	174.3	35.1	43.8	150.6
1986	95	1334.8	1545.3	191.6	927.3	1128.1	224.7	28.8	47.6	164.5
1987	288	1743.3	1897.1	174.2	1054.7	1244.8	191.5	37.0	53.8	157.2
1988	195	1537.6	1831.0	158.1	1036.2	1400.9	160.0	42.6	53.3	145.8
1989	225	2253.9	2344.4	134.3	1446.3	1685.6	139.6	57.2	70.5	140.7
1990	205	2289.9	2565.5	106.6	1636.4	2152.1	112.2	41.0	53.2	101.9
1991	210	2255.2	2398.5	183.5	1852.4	2229.4	208.7	52.5	66.7	160.8
1992	202	2652.5	2795.1	154.5	1852.6	1957.9	154.5	69.1	85.4	144.0
1993	185	2823.0	2471.3	112.4	2386.2	3022.2	121.0	75.7	80.8	114.5
1994	210	2102.8	2471.0	106.4	2322.7	2730.5	111.2	79.8	97.4	102.9
1995	194	2186.9	2287.9	113.6	2068.9	2187.8	122.2	117.8	118.3	114.4
1996	199	2397.4	2595.2	126.5	2761.4	3230.4	126.6	107.5	129.6	129.5

Note: Descriptive statistics of the LISS, RMLS and ECPF reporting mean, interquantile range (IQR) and price index P. LISS quantities consumed per month are inflated to 2005 prices and denoted in Euro (source: Eurostat `http://www.ecb.europa.eu/stats/prices/hicp/html/hicp_coicop_inx_index.en.html`). RMLS quantities are per week and inflated to 2014 prices and denoted in local currency (Russian Ruble). Goods are aggregated to composite good categories as follows. Dairy: Canned/powdered milk, fresh milk, sour milk products and sour cream; Bread: White (wheat) bread and black (rye) bread; Meat: Canned meat, beef/veal, lamb/goat, pork, giblets, poultry, lard, sausage and semi-prepared meat products. ECPF consumption is per week with quarterly collection frequency. We only report descriptive statistics of the first quarter of a given year. ECPF quantities are normalized to arbitrary units using the price indices P.

Table 7: Descriptive Statistics (Public Goods)

Longitudinal Internet Studies for the Social Sciences (LISS)

		Housing			Transport			Energy		
Year	*N*	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
2009	5594	590.6	460.0	108.1	141.1	150.0	107.4	282.0	123.0	98.6
2010	5337	600.1	449.5	109.7	135.2	150.0	105.3	210.4	125.5	98.0
2012	5463	577.4	475.0	113.4	148.2	150.0	106.6	219.1	116.0	100.4

Russian Longitudinal Monitoring Survey (RMLS)

		Housing			Transport			Energy		
Year	*N*	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
2000	1506	4388.4	6051.9	116.3	2942.3	670.7	29.0	3454.2	0.0	5.7
2005	1601	7961.1	9264.3	118.0	2996.0	2282.5	117.9	3808.0	1280.2	18.0
2010	2839	12336.3	11699.2	102.7	3697.7	2437.6	240.0	3976.4	2226.7	43.8
2011	2983	12324.6	11744.0	112.1	3697.0	2500.1	234.0	4496.1	2500.1	48.3
2012	3154	12349.8	11444.4	112.1	3799.7	2699.0	250.5	4413.2	3922.6	55.3
2013	3076	13018.6	11098.5	103.6	4109.9	2591.4	270.9	4958.9	4311.5	63.6
2014	2516	13576.1	11050.0	105.1	4169.0	2550.0	275.3	5238.0	5100.0	63.8

Spanish Continuous Family Expenditure Survey (ECPF)

		Clothing			Transport			Petrol		
Year	*N*	Mean	IQR	P	Mean	IQR	P	Mean	IQR	P
1985	65	1284.4	1406.4	165.7	553.0	942.6	188.9	183.4	41.8	92.7
1986	95	1334.8	1545.3	191.6	647.9	1002.6	277.0	120.8	0.0	112.4
1987	288	1743.3	1897.1	174.2	612.5	1000.7	213.2	190.3	48.6	98.2
1988	195	1537.6	1831.0	158.1	658.1	1050.2	154.2	244.0	172.8	86.4
1989	225	2253.9	2344.4	134.3	681.2	1120.6	119.6	397.2	314.0	95.1
1990	205	2289.9	2565.5	106.6	617.2	1017.1	115.1	451.4	254.2	114.6
1991	210	2255.2	2398.5	183.5	999.5	1252.6	244.6	493.3	398.2	105.0
1992	202	2652.5	2795.1	154.5	838.8	1307.8	147.2	459.3	437.0	90.6
1993	185	2823.0	2471.3	112.4	1099.0	1631.4	119.9	481.2	318.0	122.4
1994	210	2102.8	2471.0	106.4	1101.0	1559.4	114.4	752.0	959.9	113.4
1995	194	2186.9	2287.9	113.6	1005.7	1470.0	119.4	497.9	561.0	125.1
1996	199	2397.4	2595.2	126.5	1302.5	1954.3	112.1	667.5	938.7	106.3

Note: Descriptive statistics of the LISS, RMLS and ECPF reporting mean, interquantile range (IQR) and price index P. LISS quantities consumed per month are inflated to 2005 prices (CPI and HPI) and denoted in Euro (source: Eurostat `http://www.ecb.europa.eu/stats/prices/hicp/html/hicp_coicop_inx_index.en.html`). RMLS quantities are per week and inflated to 2014 prices and denoted in local currency (Russian Ruble). Goods are aggregated to composite good categories as follows. Transport: Transportation services, running costs for cars (excluding fuel) and Energy: Fuel, Gas, Coal and Firewood. ECPF consumption is per week with quarterly collection frequency. We only report descriptive statistics of the first quarter of a given year. ECPF quantities are normalized to arbitrary units using the price indices P. We chose a combination of private and public goods due to the limited availability of the latter.

Table 1: Results for Private Goods with Exogenous Prices

Longitudinal Internet studies for the Social Sciences (LISS)

Years	$N^{\text{total}}_{\text{couples}}$	$N^{\text{rational}}_{\text{couples}}$	$N^{\text{total}}_{\text{singles}}$	$N^{\text{rational}}_{\text{singles}}$	p-value
2009 2010 2012	715	663	542	466	0.000

Russian Longitudinal Monitoring Survey (RLMS)

Years	$N^{\text{total}}_{\text{couples}}$	$N^{\text{rational}}_{\text{couples}}$	$N^{\text{total}}_{\text{singles}}$	$N^{\text{rational}}_{\text{singles}}$	p-value
2012 2013 2014	327	315	305	295	0.027
2011 2013 2014	316	304	281	275	0.017
2011 2012 2014	314	307	283	276	0.020
2011 2012 2013	332	321	312	306	0.187
2010 2013 2014	258	249	217	213	0.033
2010 2012 2014	256	248	221	217	0.060
2010 2012 2013	268	257	243	235	0.043
2010 2011 2013	268	260	239	235	0.057
2010 2011 2012	298	293	268	262	0.120
2005 2011 2012	264	256	220	214	0.180

Spanish Continuous Family Expenditure Survey (ECPF)

Years	$N^{\text{total}}_{\text{couples}}$	$N^{\text{rational}}_{\text{couples}}$	$N^{\text{total}}_{\text{singles}}$	$N^{\text{rational}}_{\text{singles}}$	p-value
19943 19941 19942	111	106	6	6	0.007
19934 19941 19942	111	106	8	8	0.000
19922 19923 19921	97	88	16	13	0.000
19904 19911 19912	98	94	14	13	0.020
19893 19891 19892	113	105	6	6	0.000
19882 19883 19884	106	103	7	5	0.000
19871 19872 19873	131	128	8	6	0.000
19864 19871 19872	164	157	9	6	0.003
19863 19864 19871	141	135	8	7	0.000
19863 19864 19862	135	130	9	8	0.007

Note: Number of total couples, rational couples according to aggregate CARP, total singles and rational singles according to SARP, for different combinations of periods.

Table 2: Results Conditional on Demographics for Private Goods, Exogenous Prices

Longitudinal Internet studies for the Social Sciences (LISS)

Years	College	Age	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2009 2010 2012	1	2	97	93	91	80	0.077
2009 2010 2012	1	1	191	178	108	90	0.000
2009 2010 2012	1	0	84	76	75	64	0.083
2009 2010 2012	0	2	156	142	146	113	0.000
2009 2010 2012	0	1	141	125	96	74	0.000
2009 2010 2012	0	0	42	37	26	21	0.003

Russian Longitudinal Monitoring Survey (RLMS)

Years	Age	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2012 2013 2014	2	76	75	137	131	0.003
2012 2013 2014	1	201	191	134	131	0.000
2012 2013 2014	0	50	49	34	33	0.010
2011 2013 2014	2	70	69	124	120	0.000
2011 2013 2014	1	194	185	121	120	0.000
2011 2013 2014	0	52	50	36	35	0.183
2011 2012 2014	2	71	70	125	121	0.000
2011 2012 2014	1	193	188	123	121	0.043
2011 2012 2014	0	50	49	35	34	0.050
2011 2012 2013	2	78	77	138	132	0.060
2011 2012 2013	1	198	190	131	131	0.010
2011 2012 2013	0	56	54	43	43	0.010
2010 2013 2014	2	53	53	89	86	0.020
2010 2013 2014	1	153	145	93	92	0.070
2010 2013 2014	0	52	51	35	35	0.000
2010 2012 2014	2	53	53	91	87	0.000
2010 2012 2014	1	151	145	96	96	0.003
2010 2012 2014	0	52	50	34	34	0.017
2010 2012 2013	2	59	59	101	95	0.000
2010 2012 2013	1	154	144	103	102	0.003
2010 2012 2013	0	55	54	39	38	0.040
2010 2011 2013	2	59	59	101	97	0.027
2010 2011 2013	1	155	149	99	99	0.000
2010 2011 2013	0	54	52	39	39	0.200
2010 2011 2012	2	77	77	120	115	0.003
2010 2011 2012	1	164	160	107	107	0.040
2010 2011 2012	0	57	56	41	40	0.007
2005 2011 2012	2	52	50	104	101	0.083
2005 2011 2012	1	122	119	77	75	0.053
2005 2011 2012	0	90	87	39	38	0.100

Note: Number of total couples, rational couples according to aggregate CARP, total singles and rational singles according to SARP, for different combinations of periods and demographics.

Table 3: Results for Public Goods with Exogenous Prices

Longitudinal Internet studies for the Social Sciences (LISS)

Years	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2009 2010 2012	1650	1325	498	412	0.000

Russian Longitudinal Monitoring Survey (RLMS)

Years	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2012 2013 2014	327	299	305	284	0.033
2011 2013 2014	316	296	281	258	0.007
2011 2012 2014	314	295	283	261	0.030
2011 2012 2013	332	301	312	282	0.027
2010 2013 2014	258	238	217	200	0.050
2010 2012 2014	256	239	221	201	0.107
2010 2012 2013	268	241	243	218	0.013
2010 2011 2013	268	246	239	214	0.013
2010 2011 2012	298	277	268	243	0.053
2005 2011 2012	264	240	220	192	0.037

Spanish Continuous Family Expenditure Survey (ECPF)

Years	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
19943 19941 19942	111	105	6	4	0.080
19934 19941 19942	111	105	8	4	0.000
19922 19923 19921	97	90	16	15	0.000
19904 19911 19912	98	94	14	12	0.000
19893 19891 19892	113	104	6	3	0.023
19882 19883 19884	106	94	7	4	0.100
19871 19872 19873	131	121	8	6	0.030
19864 19871 19872	164	152	9	5	0.040
19863 19864 19871	141	127	8	7	0.000
19863 19864 19862	135	120	9	9	0.000

Note: Number of total couples, rational couples according to aggregate CARP, total singles and rational singles according to SARP, for different combinations of periods.

Table 4: Results Conditional on Demographics for Public Goods, Exogenous Prices

Longitudinal Internet studies for the Social Sciences (LISS)

Years	College	Age	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2009 2010 2012	1	2	199	166	83	74	0.020
2009 2010 2012	1	1	469	401	96	82	0.000
2009 2010 2012	1	0	259	207	69	47	0.040
2009 2010 2012	0	2	289	246	135	117	0.003
2009 2010 2012	0	1	318	250	88	74	0.023
2009 2010 2012	0	0	91	63	24	18	0.287

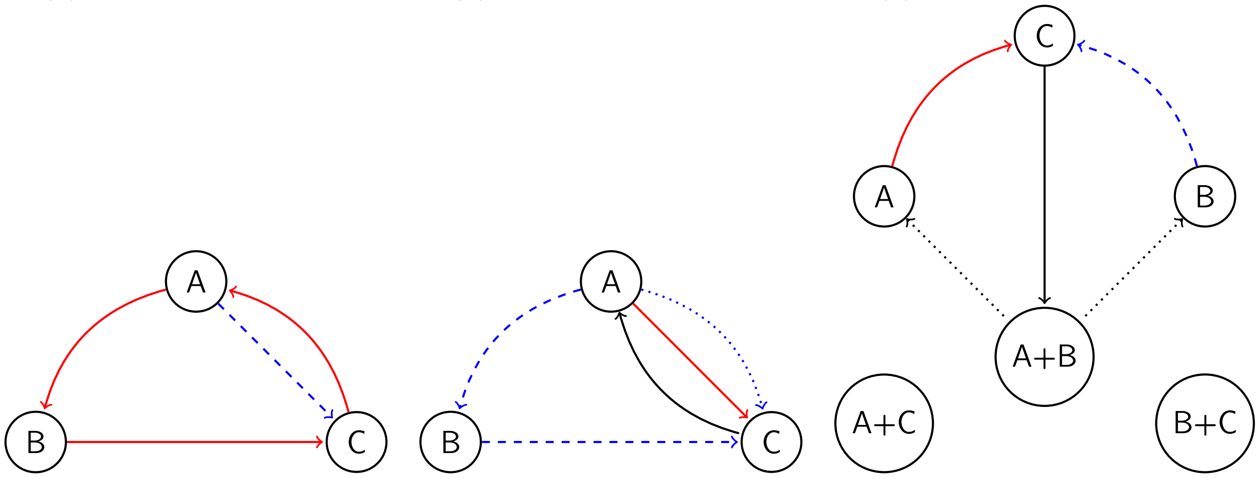
Russian Longitudinal Monitoring Survey (RLMS)

Years	Age	$N^{total}_{couples}$	$N^{rational}_{couples}$	$N^{total}_{singles}$	$N^{rational}_{singles}$	p-value
2012 2013 2014	2	76	68	137	128	0.017
2012 2013 2014	1	201	180	134	124	0.017
2012 2013 2014	0	50	44	34	32	0.207
2011 2013 2014	2	70	65	124	114	0.000
2011 2013 2014	1	194	180	121	112	0.007
2011 2013 2014	0	52	50	36	31	0.000
2011 2012 2014	2	71	65	125	114	0.020
2011 2012 2014	1	193	178	123	115	0.020
2011 2012 2014	0	50	49	35	31	0.010
2011 2012 2013	2	78	71	138	124	0.037
2011 2012 2013	1	198	174	131	119	0.017
2011 2012 2013	0	56	52	43	39	0.000
2010 2013 2014	2	53	48	89	81	0.023
2010 2013 2014	1	153	140	93	86	0.063
2010 2013 2014	0	52	48	35	32	0.020
2010 2012 2014	2	53	46	91	80	0.023
2010 2012 2014	1	151	143	96	90	0.100
2010 2012 2014	0	52	49	34	30	0.033
2010 2012 2013	2	59	53	101	90	0.020
2010 2012 2013	1	154	135	103	92	0.060
2010 2012 2013	0	55	49	39	36	0.000
2010 2011 2013	2	59	54	101	91	0.010
2010 2011 2013	1	155	138	99	90	0.010
2010 2011 2013	0	54	52	39	33	0.000
2010 2011 2012	2	77	70	120	107	0.033
2010 2011 2012	1	164	151	107	99	0.007
2010 2011 2012	0	57	55	41	37	0.050
2005 2011 2012	2	52	45	104	89	0.010
2005 2011 2012	1	122	110	77	70	0.057
2005 2011 2012	0	90	78	39	33	0.110

Note: Number of total couples, rational couples according to aggregate CARP, total singles and rational singles according to SARP, for different combinations of periods and demographics.

Table 5: Violations of the Collective Axiom

(1) Indvidiual violation (2) Household violation (3) Double-sum violation



Note: Nodes refer to different consumption bundles. The red solid line to the wife's preference relation R_0^f, the red dotted line to the implied transitive closure R^f, the blue dashed line to the husband's preference relation R_0^m, and the black solid line to the household "preference" relation.