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DISCUSSION PAPER

Modeling collective rationality: A nonparametric test on experimental data*

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Abstract

We provide a first nonparametric (revealed preference) test of the collective consumption model on the basis of experimental data. By using nonparametric testing tools and experimental data, we avoid the usual problems associated with parametric tests (e.g. non-verifiable parametric structure) and the use of 'real life'data sets (e.g. preference heterogeneity). In addition, our collective rationality test complements the existing nonparametric-experimental evidence on individual rationality. Focusing on dyads, we find that all observed consumption choices are consistent with the nonparametric collective rationality conditions. In fact, the consistency results for the parsimonious 'egoistic' collective consumption model (as a tool for describing dyads' choice behavior) are closely similar to those for the individual rationality model (as a tool for describing individuals' choice behavior). This suggest that for simple consumption decision settings, such as that considered in our experiment, the egoistic model may be useful for practical analysis. Still, our results also suggest that the more general collective consumption model, which accounts for consumption externalities and public consumption, can be useful even for modeling such simple decision settings. In fact, we can interpret that the appropriate model specification also depends on the specific dyad type (e.g. friends or partners; gender composition) and choice setting (e.g. public consumption or not) at hand.

Key words: collective consumption decisions, Generalized Axiom of Revealed Preference, nonparametric analysis, experimental data.

JEL-classification: C14, C92, D11, D12, D13.

1. Introduction

Many consumption decisions are taken collectively, and many such collective decisions are taken under a joint budget constraint. A most notable example is household consumption; the different household members should agree upon the allocation of the aggregate household budget. But there are a lot of other situations that involve groups of individuals spending a joint budget. See e.g. Chiappori and Ekeland (2006) for examples.

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This paper focuses on the so-called 'collective consumption model' introduced by Chiappori (1988) as a tool for modeling *rational* collective decision making.[1] This model explicitly recognizes the multi-person nature of the collective choice process, with each individual decision maker characterized by her/his own rational preferences. It (only) assumes that the observed group consumption is the *Pareto efficient* outcome of a bargaining process within the group; see e.g. Chiappori (1988, 1992), Browning and Chiappori (1988), and Chiappori and Ekeland (2006) for discussion of this Pareto efficiency assumption in the context of group decision making. A highly attractive feature of the model is that it starts from the preferences of the individuals constituting the group. For example, Browning, Chiappori and Lewbel (2005) convincingly advocate the collective consumption model by arguing that individuals (e.g. the household members) and not the 'aggregate' group as such (e.g. the household) should be the focal point in welfare analysis.

In fact, the model does not only have a solid conceptual basis, it is also well supported by the empirical evidence; see e.g. Vermeulen (2004) for a survey of studies that focus on household consumption. Still, existing empirical studies are typically *parametric* in nature, i.e. they critically rely on a (non-verifiable) functional structure for representing the group member preferences and the within-group bargaining processes. As a matter of fact, parametric tests simultaneously test the consumption model under study *as well as* a parametric structure that is imposed on the model. In addition, the existing evidence is typically based on *real-life* data sets, which involves often controversial preference homogeneity assumptions (excluding e.g. changing preferences) and data measurement problems. These problems can seriously distort the empirical analysis, and may put into question -at least to some extent- the reliability of the conclusions that are drawn from it.

These testing problems provide the prime motivation for the current study. Specifically, we present a *nonparametric* (revealed preference) test of the collective consumption model on the basis of *experimental* data. The use of nonparametric tools should provide a more convincing case for the goodness of the collective model (as compared to the existing parametric evidence), essentially because it does not require debatable *a priori*'s. In addition, the laboratory nature of experiments effectively avoids the usual preference heterogeneity and data problems. In fact, it has been argued that the nonparametric testing tools are especially useful within an experimental context; a particularly convincing case is provided by Sippel (1997), who focused on individual rationality (see e.g. Afriat (1967) and Varian (1982, 2006) for the corresponding so-called 'revealed preference' conditions). In addition, and specific for our own study, the experimental set-up allows for obtaining information on consumption quantities for the individual group members; such information is typically not available in 'real life' data sets (e.g. household data sets usually only contain consumption quantity information at the level of the aggregate household as a whole, and do not reveal the individual members' consumption quantities). This additional information allows more powerful tests of the collective consumption model.

Our study also complements the existing nonparametric-experimental literature that focuses on the goodness of the utility maximization model for describing rational individual behavior; see e.g. Sippel (1997), Harbaugh, Krause and Berry (2001), Andreoni and Miller (2002) and references therein. The collective model, which -to recall- explicitly recognizes the individual preferences, can be interpreted as the natural extension of the individual utility maximization model. Therefore, it is interesting to investigate to what extent the model indeed does succeed in describing observed group behavior, using similar nonparametric tools within an experimental context. The current study provides a first such test. More generally, it demonstrates the potential of the nonparametric analysis of experimental data for gaining insight in group decision processes; see our discussion in the concluding section.

Apart from a mere test of collective rationality as such, the second main question that we

[1] Chiappori (1988) focused on labor supply behavior. Browning and Chiappori (1998) extended Chiappori's original model to apply for general consumption settings.

want to address pertains to the specification of the collective model itself. The most simple collective consumption model, which we will refer to as the *egoistic model*, excludes public consumption and consumption externalities (also referred to as 'altruism' in the following) within the decision making group.[2] By contrast, the most *general model*, proposed by Browning and Chiappori (1998), does allow for public consumption as well as consumption externalities. Cherchye, De Rock and Vermeulen (2006) recently presented a nonparametric characterization of this general model; and they subsequently suggested nonparametric tests for data consistency with that model. As we will show, starting from the nonparametric characterization for the general model, it is easy to define testable necessary and sufficient conditions for data consistency with the egoistic model.

Our empirical analysis first investigates consistency of choice behavior with the general collective model as well as with the egoistic model in a simple consumption setting (involving a very limited number of commodities and a low budget; see the experimental design in Section 3). Consistency with the simple egoistic model may seem convenient from a practical point of view: the parsimonious nature of the model allows for a powerful empirical analysis (e.g. in terms of recovering the preference structure of individual group members and the characteristics of the within-group bargaining process, and in terms of forecasting group behavior in new situations). Subsequently, we interpret the cases that are inconsistent with the egoistic model but consistent with the general model in terms of possible consumption externalities and public consumption. In doing so, we also consider the specific characteristics of the decision making groups (*in casu* dyads; e.g. partners versus friends, and differences in terms of gender composition) and the choice setting (i.e. possibility of public consumption or not). This can suggest guidelines regarding the appropriate collective consumption model to use depending on the specific setting under investigation.

The rest of the paper unfolds as follows. Section 2 introduces the nonparametric tests for collective rationality. Section 3 presents the experimental design. Section 4 discusses the results of our empirical analysis. Section 5 summarizes and contains some concluding remarks.

2. Rational consumption decisions: nonparametric tests

2.1. Individual rationality

Before introducing the collective rationality tests, we define the nonparametric condition for individual rationality. Indeed, individually rational behavior is a prerequisite for collectively rational behavior. As we explain in greater detail in Section 3, our experiment contained two stages for all participants: in one stage they had to choose individually the quantities they wanted to consume under alternative price regimes; in the other stage they had to decide collectively upon the consumption quantities under the same price regimes.[3]

Suppose we observe T individual choices of n-valued bundles. For each observation j the vector $\mathbf{q}_j \in \mathbb{R}^n_+$ denotes the chosen quantities under the prices $\mathbf{p}_j \in \mathbb{R}^n_{++}$; and $S = \{(\mathbf{p}_j; \mathbf{q}_j), j = 1, ..., T\}$ represents the set of all observations for the individual under study. A necessary and sufficient condition for the individual behavior to be consistent with the utility

[2] This is essentially the original collective consumption model as it was presented by Chiappori (1988) (for modeling labor supply behavior). In what follows, consumption externalities mean that the utility of one group member depends (positively) on the (private) consumption of other group members; and public consumption, which contrasts with private consumption, indicates that the same commodity is consumed simultaneously by several group members (e.g. watching a movie together). Of course, the consumption of a commodity may well be partly private (possibly characterized by consumption externalities) and partly public.

[3] One group of participants had to choose individually in the first stage and collectively in the second stage, while another group had to choose collectively in the first stage and individually in the second stage (see Section 3). Changing the order in this way did not yield significantly different results in terms of (individual or collective) rationality.

maximization hypothesis is that there exists a (nonsatiated) utility function U that *rationalizes* the individual data, i.e. for all $j \in \{1, ..., T\}$ the value $U(\mathbf{q}_j)$ equals

$$\max_{\mathbf{q} \in \mathbb{R}^n_+} U(\mathbf{q}) \text{ s.t. } \mathbf{p}'_j \mathbf{q} \leq \mathbf{p}'_j \mathbf{q}_j. \tag{2.1}$$

Varian (1982) has demonstrated that such a data rationalizing utility function exists if and only if the observed set S is consistent with the *Generalized Axiom of Revealed Preference* (*GARP*). To formally state this last consistency condition, we first need the following definition:

Definition 1. *For a set of observations* $S = \{(\mathbf{p}_j; \mathbf{q}_j); j = 1, ..., T\}$*: if* $\mathbf{p}'_i \mathbf{q}_i \geq \mathbf{p}'_i \mathbf{q}_j$ *then* $\mathbf{q}_i \; R_0 \; \mathbf{q}_j$*; and if* $\mathbf{q}_i \; R_0 \; \mathbf{q}_k$, $\mathbf{q}_k \; R_0 \; \mathbf{q}_l$, ..., $\mathbf{q}_z \; R_0 \; \mathbf{q}_j$ *for some (possibly empty) sequence* $(k, l, ..., z)$ *then* $\mathbf{q}_i \; R \; \mathbf{q}_j$.

The relation R_0 is commonly referred to as the *direct revealed preference* relation, while its transitive closure R is known as the *revealed preference* relation. Using Definition 1, we can define the *Generalized Axiom of Revealed Preference* (*GARP*).

Definition 2. *A set of observations* $S = \{(\mathbf{p}_j; \mathbf{q}_j); j = 1, ..., T\}$ *satisfies* GARP *if* $\mathbf{p}'_j \mathbf{q}_j \leq \mathbf{p}'_j \mathbf{q}_i$ *whenever* $\mathbf{q}_i \; R \; \mathbf{q}_j$.

The *GARP* provides the basis for a test of *individual rationality.* Essentially, this test proceeds in two steps: one first recovers the relations R_0 and R, to subsequently check the upper cost bound condition in Definition 2. See Varian (1982; p. 949) for an efficient algorithm.

To capture the degree of consistency with *GARP*, we use the so-called 'Afriat efficiency index', which is defined as follows for each observation j:

$$\theta^j = \frac{\min_{\mathbf{q}_i R \mathbf{q}_j} \mathbf{p}'_j \mathbf{q}_i}{\mathbf{p}'_j \mathbf{q}_j}; \tag{2.2}$$

the measure θ^j divides the expenditure level that is needed for obtaining consistency with *GARP* ($\min_{\mathbf{q}_i R \mathbf{q}_j} \mathbf{p}'_j \mathbf{q}_i$) by the actual expenditure level $\mathbf{p}'_j \mathbf{q}_j$. Evidently, rational (or 'efficient') behavior complies with $\theta^j = 1$. More generally, the value of θ^j captures the expenditure reduction that is required for obtaining consistency with the utility maximization problem. The corresponding Afriat efficiency index for the observed set S takes the minimum θ^j over all T choices:

$$\theta = \min \left\{ \theta^j \mid (\mathbf{p}_j; \mathbf{q}_j) \in S \right\}; \tag{2.3}$$

the measure θ can be interpreted as a 'goodness-of-fit' measure in that it indicates to what extent utility maximization effectively fits the observed individual choice behavior. We refer to Varian (1990) for a detailed discussion.

2.2. Collective rationality: the general model

For simplicity, our empirical investigation of the collective rationality model focuses on two-member groups, or 'dyads' for short.[4] For all dyads, the collective model assumes that each individual decision maker has her or his own rational preferences, which can be represented by a well-behaved individual utility function. Since the general collective consumption model allows for both externalities and public consumption inside the group, it is not the aggregate group

[4]In this respect, it is worth noting that Cherchye, De Rock and Vermeulen (2006) also developed a nonparametric characterization of collective rationality and corresponding operational tests for the general case of M-person groups ($M \geq 2$). We see a nonparametric-experimental investigation of such multi-person collective rationality as an interesting avenue for follow-up research.

consumption bundle that generates utility for the individuals, but the *disaggregated* intra-dyad allocation of this bundle: for a group consumption bundle $\mathbf{q}$, this intra-dyad allocation can be represented by *personalized quantities* $\widehat{\mathbf{q}} = \left(\mathfrak{q}^1, \mathfrak{q}^2, \mathfrak{q}^h\right)$ such that

$$\mathbf{q} = \mathfrak{q}^1 + \mathfrak{q}^2 + \mathfrak{q}^h, \tag{2.4}$$

with $\mathfrak{q}^1$ and $\mathfrak{q}^2$ (both $\in \mathbb{R}^n_+$) the private consumption quantities of group members 1 and 2, and $\mathfrak{q}^h$ ($\in \mathbb{R}^n_+$) the public consumption quantities. In principle, a consumption commodity can be used for private consumption as well as public consumption (or combinations of both). Of course, for some commodities public consumption can be excluded *a priori* (e.g. in our own experiment this is the case for the commodities red wine, orange juice and M&Ms). As explained in Section 3, for those commodities the specific set-up of our experiment allows us to fully recover the privately consumed quantities (i.e. the corresponding entries of $\mathfrak{q}^1$ and $\mathfrak{q}^2$). This will prove useful in our following discussion of the so-called 'egoistic' model. As for the current section, however, we abstract from this information to keep the exposition simple. Ignoring this information does not fundamentally affect any of the rationality conditions stated below.

Given (2.4), individual preferences defined over the intra-dyad allocation are represented by (monotonically increasing) utility functions $U^1(\widehat{\mathbf{q}})$ for member 1 and $U^2(\widehat{\mathbf{q}})$ for member 2.[5] Thus, both members' utilities depend on $\mathfrak{q}^1$ and $\mathfrak{q}^2$, which captures the possibility of consumption externalities (or altruism), as well as on $\mathfrak{q}^h$, which captures public consumption.

A second fundamental characteristic of the collective consumption model is that it assumes Pareto efficient within-group allocations. Using this, we follow Browning and Chiappori (1998) to define a necessary and sufficient condition for *collective rationality.* To do so, let us again start from a set of T observations $S = \{(\mathbf{p}_j; \mathbf{q}_j), j = 1, ..., T\}$, which is now defined at the level of the dyad that is evaluated. A pair of (monotonically increasing) utility functions U^1 and U^2 *collectively rationalize* the set S if and only if: there exists a set of personalized quantities $\{\widehat{\mathbf{q}}_j; j = 1, ..., T\}$ and a set of weights $\left\{\boldsymbol{\mu}_j \in \mathbb{R}_{++}; j = 1, ..., T\right\}$ such that for each observation j the value $U^1\left(\widehat{\mathbf{q}}_j\right) + \boldsymbol{\mu}_j U^2\left(\widehat{\mathbf{q}}_j\right)$ equals

$$\max_{\left(\mathfrak{q}^1,\mathfrak{q}^2,\mathfrak{q}^h\right)\in\left(\mathbb{R}^n_+\right)^3} U^1\left(\mathfrak{q}^1, \mathfrak{q}^2, \mathfrak{q}^h\right) + \boldsymbol{\mu}_j U^2\left(\mathfrak{q}^1, \mathfrak{q}^2, \mathfrak{q}^h\right) \text{ s.t. } \mathbf{p}_j' \begin{pmatrix} \mathfrak{q}^1 \\ \mathfrak{q}^2 \\ \mathfrak{q}^h \end{pmatrix} \leq \mathbf{p}_j'\mathbf{q}_j. \tag{2.5}$$

In this definition, the weight μ_j represents the relative 'bargaining power' (*vis-à-vis* member 1) of member 2; this bargaining power may vary according to the specific observation/situation j at hand. In words, the collective consumption model (2.5) generalizes the standard (individual) utility maximization model (2.1) by describing group behavior as maximizing a weighted sum of the individual member utilities. The weighting of the utilities reflects the Pareto efficiency characterization of optimal group allocations.

Cherchye, De Rock and Vermeulen (2006) established a nonparametric characterization of the general collective rationality condition captured in (2.5). To introduce that characterization, we first define *personalized prices* $\left(\widehat{\mathbf{p}}_j^1, \widehat{\mathbf{p}}_j^2\right)$ for observed aggregate prices $\mathbf{p}_j$, as follows:

$$\begin{aligned} \widehat{\mathbf{p}}_j^1 &= \left(\mathfrak{p}_j^1, \mathfrak{p}_j^2, \mathfrak{p}_j^h\right) \text{ and } \widehat{\mathbf{p}}_j^2 = \left(\mathbf{p}_j - \mathfrak{p}_j^1, \mathbf{p}_j - \mathfrak{p}_j^2, \mathbf{p}_j - \mathfrak{p}_j^h\right) \text{ with} \\ \mathfrak{p}_j^1, \mathfrak{p}_j^2, \mathfrak{p}_j^h &\in \mathbb{R}^n_+ \text{ and } \mathfrak{p}_j^c \leq \mathbf{p}_j \;\; (c = 1, 2, h). \end{aligned} \tag{2.6}$$

This concept complements the concept of personalized quantities (see 2.4): $\widehat{\mathbf{p}}_j^1$ and $\widehat{\mathbf{p}}_j^2$ capture the fraction of the price for the personalized quantities $\widehat{\mathbf{q}}_j$ that is borne by, respectively, member

[5] The fact that we regard monotonically increasing utility functions in principle excludes negative consumption externalities within the household. Admittedly, this assumption may be restrictive in some instances (e.g. tobacco consumption). But we believe it harmless in the present context given the specific set-up of our experiment (which includes the commodities red wine, orange juice and M&Ms and -in approximately half of the cases- additional consumption financed by cashed amounts).

1 and member 2. The components $\mathfrak{p}_j^1$ and $\mathfrak{p}_j^2$ pertain to private consumption quantities and compensate for consumption externalities: if the private consumption $\mathfrak{q}_j^1$ ($\mathfrak{q}_j^2$) is characterized by externalities then $\mathfrak{p}_j^1 \neq \mathbf{p}_j$ ($\mathfrak{p}_j^2 \neq \mathbf{0}$). The remaining component $\mathfrak{p}_j^h$ relates to public consumption quantities.

We can now formulate the necessary and sufficient nonparametric condition for rational behavior in terms of the general collective consumption model (Proposition 1 in Cherchye, De Rock and Vermeulen, 2006):

Proposition 1. *Let $S = \{(\mathbf{p}_j; \mathbf{q}_j); j = 1, ..., T\}$ be a set of observations. There exists a pair of concave and continuous utility functions U^1 and U^2 that provide* a collective rationalization *of S if and only if there exists a set of personalized prices and quantities $\{(\widehat{\mathbf{p}}_j^1, \widehat{\mathbf{p}}_j^2; \widehat{\mathbf{q}}_j); j = 1, ..., T\}$ such that the sets $\{(\widehat{\mathbf{p}}_j^1; \widehat{\mathbf{q}}_j); j = 1, ..., T\}$ and $\{(\widehat{\mathbf{p}}_j^2; \widehat{\mathbf{q}}_j); j = 1, ..., T\}$ both satisfy* GARP.

Thus, just like for individual rationality (see Section 2.1), collective rationality requires *GARP* consistency, but now the condition is expressed in terms of personalized prices and quantities. Specifically, the necessary and sufficient condition requires that there exists at least one feasible specification of the set $\{(\widehat{\mathbf{p}}_j^1, \widehat{\mathbf{p}}_j^2; \widehat{\mathbf{q}}_j); j = 1, ..., T\}$ that satisfies the corresponding *GARP* conditions at the level of the individual members 1 and 2.

The condition in Proposition 1 is difficult to use in practice, since it is defined in terms of unobserved personalized prices $(\widehat{\mathbf{p}}_j^1, \widehat{\mathbf{p}}_j^2)$ (although the personalized quantities $\widehat{\mathbf{q}}_j$ are partially observed; see Section 3). Therefore, in our empirical analysis we will mainly focus on the following sufficiency condition, which solely uses the observed set S and avoids reconstructing (unobserved) personalized prices and quantities (Proposition 4 in Cherchye, De Rock and Vermeulen, 2006):[6]

Proposition 2. *Let $S = \{(\mathbf{p}_j; \mathbf{q}_j); j = 1, ..., T\}$ be a set of observations. There exists a pair of concave and continuous utility functions U^1 and U^2 that provide* a collective rationalization *of S if there exists a partitioning S_1, S_2 ($S_1 \cup S_2 = S$; $S_1 \cap S_2 = \emptyset$) such that the sets S_1 and S_2 both satisfy* GARP.

Following Cherchye, De Rock and Vermeulen (2006), the group decision model underlying this sufficiency condition can be interpreted as a *situation-dependent dictatorship* model. Specifically, for all observations j such that $(\mathbf{p}_j; \mathbf{q}_j) \in S^1$, member 1 is the 'dictator' who decides upon the personalized quantities $\widehat{\mathbf{q}}_j$, whereas member 2 is the dictator for the other observations. Or put another way, *the identity of the dictator depends on the observation/situation at hand.* Thus, the model implies *two* separate decision-makers in the household, who are each (*fully*) responsible for a disjoint subset of the T observed aggregate group quantities. Consequently, the sufficiency condition implies that there must exist a partitioning of the observed set S in two subsets that each individually meet the corresponding *GARP* condition; i.e. each individual dictator must act consistent with the individual rationality condition *for those quantities for which she or he is (fully) responsible.*[7]

[6] Cherchye, De Rock and Vermeulen (2006) explain the equivalence between the formulation of the sufficiency condition in Proposition 2 and their Proposition 4. In fact, they also formulated a necessary condition for collectively rational behavior. Using that condition, they show that the general collective rationality condition has testable implications (i.e. can be rejected) as soon as $T \geq 3$ and $n \geq 3$; in our application $T = 9$ and $n = 3$ *or* 4 for each evaluated dyad. In addition, they argue convergence between their necessary condition and the sufficient condition in Proposition 2 for sufficiently large T. As for our application (with $T = 9$), we choose to focus on the sufficiency condition for collective rationality given that consistency with this condition evidently implies consistency with any necessity condition.

[7] In their general setting, Cherchye, De Rock and Vermeulen (2006) assume ignorance regarding the specification of the personalized quantities $\widehat{\mathbf{q}}_j$, whereas in our experimental set-up we do have (partial) information on $\widehat{\mathbf{q}}_j$. Still, the formal argument of these authors is readily adapted to obtain the same situation-dependent dictatorship interpretation for the current context.

To conclude, we indicate that testing data consistency with the sufficiency condition in Proposition 2 involves a finite process. Specifically, it requires checking *GARP* consistency for at most 2^T alternative specifications of the sets S_1 and S_2.

2.3. Collective rationality: the egoistic model

The general collective consumption model presented in the previous section allows for both consumption externalities and public consumption within the group. As discussed in the Introduction, our empirical investigation will also focus on a parsimonious specification of the collective consumption model, which excludes consumption externalities as well as public consumption. This obtains a model of group behavior in which the utility of each member *only* depends on her or his private consumption (i.e. $U^1(\widehat{\mathbf{q}}) = U^1(\mathfrak{q}^1)$ and $U^2(\widehat{\mathbf{q}}) = U^2(\mathfrak{q}^2)$ in (2.5)), whence we call it the *egoistic* model. In fact, as mentioned before, the specific set-up of our experiment allows for recovering the personalized quantities $\mathfrak{q}^1$ and $\mathfrak{q}^2$ (if we exclude public consumption, i.e. $\mathfrak{q}^h = \mathbf{0}$). This in turn allows for a necessary and sufficient nonparametric test for collectively rational group behavior in terms of this egoistic model.[8]

To obtain that test, we first note that excluding consumption externalities implies for each observation j that $\mathfrak{p}_j^1 = \mathbf{p}_j$ and $\mathfrak{p}_j^2 = \mathbf{0}$, so that the personalized prices $\widehat{\mathbf{p}}_j^1 = \left(\mathfrak{p}_j^1, \mathfrak{p}_j^2\right) = (\mathbf{p}_j, \mathbf{0})$ and $\widehat{\mathbf{p}}_j^2 = \left(\mathbf{p}_j - \mathfrak{p}_j^1, \mathbf{p}_j - \mathfrak{p}_j^2\right) = (\mathbf{0}, \mathbf{p}_j)$ (we can ignore public consumption ($\mathfrak{p}_j^h$) since $\mathfrak{q}_j^h = \mathbf{0}$ by construction). Hence, given that also $\mathfrak{q}_j^1$ and $\mathfrak{q}_j^2$ are fully observed, we effectively dispose of all relevant personalized price and quantity information for the egoistic model. Starting from the corresponding set of observations $\widehat{S} = \left\{\left(\mathbf{p}_j; \mathfrak{q}_j^1, \mathfrak{q}_j^2\right); j = 1, ..., T\right\}$ for the evaluated dyad, the nonparametric condition follows directly from Proposition 1:

Corollary 1. *Let $\widehat{S} = \left\{\left(\mathbf{p}_j; \mathfrak{q}_j^1, \mathfrak{q}_j^2\right); j = 1, ..., T\right\}$ be a set of observations. There exists a pair of concave and continuous utility functions U^1 and U^2 that provide an* egoistic rationalization *of S if and only if the sets $\left\{\left(\mathbf{p}_j; \mathfrak{q}_j^1\right); j = 1, ..., T\right\}$ and $\left\{\left(\mathbf{p}_j; \mathfrak{q}_j^2\right); j = 1, ..., T\right\}$ both satisfy* GARP.

Thus, testing consistency with the egoistic model is formally similar to testing consistency with the individual rationality model: for each individual member we test consistency with the *GARP* condition using the observed set $\widehat{S}$; *egoistic rationality* is obtained if both members simultaneously meet the corresponding individual rationality conditions. Correspondingly, we can use an analogously defined Afriat efficiency index as in (2.3) for capturing the degree of consistency with the egoistic model:

$$\theta = \min\left\{\theta^j \mid \left(\mathbf{p}_j; \mathfrak{q}_j^1, \mathfrak{q}_j^2\right) \in \widehat{S}\right\} \text{ with } \theta^j = \min\left\{\frac{\min\limits_{\mathfrak{q}_i^1 R \mathfrak{q}_j^1} \mathbf{p}_j' \mathfrak{q}_i^1}{\mathbf{p}_j' \mathfrak{q}_j^1}, \frac{\min\limits_{\mathfrak{q}_i^2 R \mathfrak{q}_j^2} \mathbf{p}_j' \mathfrak{q}_i^2}{\mathbf{p}_j' \mathfrak{q}_j^2}\right\}. \tag{2.7}$$

As compared to (2.2), each measure θ^j now captures the expenditure reduction that is required for obtaining consistency with the *GARP* conditions in Corollary 1 (based on $\widehat{S}$) *for the two dyad members simultaneously.*

As a final note, we indicate that under the egoistic model the group consumption process can also be characterized as a two-stage budgeting process (see Chiappori, 1988 and 1992). To introduce that alternative interpretation, we represent the total dyad budget/income in observation j as y_j $(= \mathbf{p}_j' \mathbf{q}_j)$. The first stage then divides this aggregate income over the dyad

[8] We also say that a commodity is 'assignable' if we can observe the private consumption of each group member. In the literature on collective consumption models, such assignability is directly related to the possibility of identifying the collective model underlying the observed consumption behavior (e.g. Browning, Bourguignon, Chiappori and Lechene, 1994). In this respect, the fact that our experimental approach allows us to fully assign each commodity under the egoistic model provides yet another argument pro using an experiment such as ours for testing the empirical validity of collective rationality models.

members on the basis of a so-called *sharing rule*; this is a function ϕ that maps the price-income combination $(\mathbf{p}_j, y_j)$ to $\phi(\mathbf{p}_j, y_j) = (y_j^1, y_j^2)$ such that $y_j^1 + y_j^2 = y_j$, with y_j^1 and y_j^2 the income shares allocated to the members 1 and 2. In the second stage, each individual member m $(= 1, 2)$ consequently faces a maximization problem that is formally similar to the individual decision problem:[9]

$$\max_{\mathfrak{q}^m} U^m(\mathfrak{q}^m) \text{ s.t. } \mathbf{p}_j' \mathfrak{q}^m \leq y_j^m. \tag{2.8}$$

Under egoistic rationality, the outcome of this two-stage process equals the observed consumption quantities $\mathfrak{q}_j^1$ and $\mathfrak{q}_j^2$ for the members 1 and 2. In fact, given $\widehat{S}$ we can reconstruct the sharing rule for the T observed consumption choices, namely $y_j^1 = \mathbf{p}_j' \mathfrak{q}_j^1$ and $y_j^2 = \mathbf{p}_j' \mathfrak{q}_j^2$. We will use this in our empirical analysis in Section 4.

3. Experimental design

Participants of our experiment were 206 undergraduate students (102 women). Ages ranged from 18 years to 29 years (mean value = 20.92; standard deviation = 1.88). As we wanted to analyze collective choice behavior, both men and women were asked to sign up for an experimental session together with either a male or a female friend or a romantic partner. This procedure enabled us to study four different types of dyads, namely, male dyads or two male friends (‘*friends (m-m)*’; 26 in total), female dyads or two female friends (‘*friends (f-f)*’; 25 in total), mixed dyads or one male and one female friend (‘*friends (f-m)*’; 25 in total), and romantic dyads or one man and one woman who were in a romantic relationship together (‘*partners (f-m)*’; 27 in total).[10] Participants were scheduled to come to the laboratory in groups of eight (i.e., four dyads). Each participant was assigned a seat in a partially enclosed cubicle, and worked individually for the main part of the session. Dyads were asked to engage in one experimental task together. Participants were rewarded with money and with a commodity bundle for their cooperation. Each dyad received money and a commodity bundle with a combined value of € 20.

Our experiment is similar in design to the one of Harbaugh, Krause, and Berry (2001). Upon entering the laboratory, participants were given the opportunity to taste small quantities of red wine, orange juice, and M&Ms. They were truthfully told that they would be making consumption decisions with respect to these three commodities later on, and that we wanted them to familiarize themselves with the commodities. Participants were then presented with 9 choice problems. For (approximately) one half of the participants (i.e. in the 3-commodities condition), each choice consisted of the three commodities red wine, orange juice, and M&Ms. Each choice problem was characterized by a different price regime; the prices of the three commodities are shown in Table 1.[11]

For each choice problem, participants were asked to indicate, according to their preferences, how much they wanted to pay for, and hence, how much they wanted to obtain from each commodity, given that the total budget they could allocate to the three commodities was €

[9] This characterization of egoistic rationality actually provides an alternative rationale for the necessary and sufficient nonparametric condition in Corollary 1: given that we know the private consumption quantities $\mathfrak{q}_j^1$ and $\mathfrak{q}_j^2$, and thus also y_j^1 $(= \mathbf{p}_j' \mathfrak{q}_j^1)$ and y_j^2 $(= \mathbf{p}_j' \mathfrak{q}_j^2)$, the maximization problem (2.8) leads to the *GARP* tests for the individual group members just like the problem (2.1) entails the *GARP* condition for individual rationality in Definition 2.

[10] Homosexual nor lesbian dyads were included in the study.

[11] This price configuration implies a high power of our rationality tests, essentially because there is no variation in income (€ 10) but a lot of variation in prices. [A similar idea for maximizing the power of nonparametric tests underlies e.g. the ‘maximum power sequential path’ presented by Blundell, Browning, and Crawford (2003).] We indicate that the price variation enables rejection of the general collective rationality condition in Proposition 1. E.g., for the given prices and income one can conceive quantity bundles that lead to a rejection of collective rationality in an analogous way as the quantity bundles in Example 1 of Cherchye, De Rock and Vermeulen (2006).

10. Obviously, for this '3-commodities group' we can exclude the possibility of public consumption: the consumption of the three commodities must be private by construction. As such, the egoistic rationality test presented in the previous section effectively tests whether or not the collective decision process is characterized by consumption externalities (or altruism): in the '3-commodities condition', dyad choice data that are consistent with the general collective consumption model but not with the egoistic model can be interpreted as revealing consumption externalities.

The other half of the participants (i.e., in the '4-commodities condition') was confronted with nine almost identical decision problems (i.e., they had to state their demand for red wine, orange juice, and M&Ms, given the same relative price variations as presented in Table 1 and a budget of € 10). The only difference is that they had the option of receiving in cash any amount of the budget they wanted to in each decision situation; the price of this additional 'cash' commodity equals 1 for all choice problems. We note that, because the destination (public or private consumption) of the cashed amount is not defined, this '4-commodities group' has the possibility of public consumption. [More generally, the fourth commodity of this 4-commodities group stands for any additional consumption (financed by the cashed amount) on top of the chosen quantities of red wine, orange juice and M&Ms.] Thus, differences between the egoistic rationality results for the 4-commodities and the 3-commodities group may be interpreted in terms of such public consumption.

Participants in both conditions were asked to make the 9 allocation decisions twice: once individually and once together with their friend or romantic partner. The order in which both sets of decisions were to be made was counterbalanced: one half of the dyads first made the decisions individually and only afterwards collectively, whereas the other half of the dyads first made the decisions collectively and only afterwards individually; Table 2 presents summary information on the budget shares corresponding with the individuals' and the dyads' choices under the 9 price regimes. In case of collective decision-making, participants were asked to indicate for each of the three commodities (and also for the cashed amount of money in the 4-commodities condition) which percentage of their demand was intended for each individual. This provides the personalized quantity information that we use for the egoistic rationality test (see Corollary 1).

The decision problems participants were faced with were supposed to mimic real-life difficulties that both individual consumers and groups often encounter when having to pick their optimal commodity bundles out of the available budget sets. To enhance the external validity of our study, participants were told that, when all experimental sessions were over (i.e., two weeks after they themselves participated at the utmost), they would actually receive one of the commodity bundles they had put together. They were also told that they would be informed through e-mail about where and when to pick it up. We picked this bundle randomly from the set of decisions that participants had made collectively (and we thus ignored the individually chosen bundles), although they were not informed of this beforehand. The knowledge that each choice ostensibly had the same chance of actually being implemented was supposed to give economic significance to otherwise merely hypothetical decisions, thus providing participants with an incentive for making choices that truly represented their preferences.

As making the allocation decisions required a considerable amount of calculation (multiplying prices and demand for each commodity and adding up to check whether the budget is exhausted), participants in both the 4-commodities and the 3-commodities condition were encouraged to use a calculator to check their decisions. Participants could also spend as much time as they liked on their decisions and were free to compare, reconsider, and correct previous choices. When they felt that the decisions they had made represented their actual preferences, the experimenter provided them with the instructions for the next task.

Table 1: experimental design - prices for the 9 choice problems

Choice problem	*Wine*	*Orange juice*	*MMs*
1	8	4	1
2	8	3	2
3	9	3	1
4	1	8	4
5	2	8	3
6	1	9	3
7	4	1	8
8	3	2	8
9	3	1	9

Notes: Prices are displayed in eurocents per commodity unit. A unit of red wine is 1 centiliter, a unit of orange juice is 3 centiliters, and a unit of M&Ms is 5 grams.

Table 2: experimental results - budget shares for the 9 choice problems

choice problem		Wine	Orange juice	MMs	Cash	Wine	Orange juice	MMs	Cash
		4-commodities - 104 individuals				*4-commodities - 52 dyads*			
1	*mean*	0.186	0.209	0.208	0.395	0.226	0.228	0.232	0.315
	st. dev.	0.218	0.181	0.230	0.285	0.243	0.197	0.239	0.267
2	*mean*	0.182	0.247	0.184	0.387	0.215	0.222	0.200	0.347
	st. dev.	0.216	0.205	0.195	0.277	0.246	0.199	0.200	0.265
3	*mean*	0.164	0.243	0.219	0.374	0.174	0.243	0.263	0.317
	st. dev.	0.213	0.204	0.239	0.284	0.231	0.218	0.262	0.278
4	*mean*	0.345	0.138	0.123	0.393	0.373	0.132	0.153	0.337
	st. dev.	0.315	0.188	0.179	0.286	0.332	0.182	0.207	0.273
5	*mean*	0.325	0.153	0.133	0.388	0.318	0.146	0.194	0.342
	st. dev.	0.273	0.200	0.174	0.270	0.288	0.187	0.224	0.270
6	*mean*	0.342	0.142	0.143	0.373	0.372	0.111	0.200	0.318
	st. dev.	0.305	0.211	0.196	0.289	0.334	0.172	0.246	0.279
7	*mean*	0.214	0.323	0.109	0.347	0.226	0.299	0.133	0.340
	st. dev.	0.230	0.290	0.180	0.277	0.254	0.272	0.213	0.294
8	*mean*	0.253	0.271	0.109	0.366	0.280	0.251	0.131	0.330
	st. dev.	0.234	0.234	0.178	0.271	0.242	0.186	0.191	0.274
9	*mean*	0.235	0.307	0.107	0.354	0.261	0.290	0.132	0.319
	st. dev.	0.237	0.269	0.191	0.286	0.277	0.264	0.230	0.287
		3-commodities - 102 individuals				*3-commodities - 51 dyads*			
1	*mean*	0.310	0.361	0.329		0.261	0.331	0.407	
	st. dev.	0.296	0.248	0.297		0.291	0.226	0.282	
2	*mean*	0.299	0.382	0.320		0.261	0.369	0.370	
	st. dev.	0.292	0.260	0.292		0.303	0.245	0.283	
3	*mean*	0.261	0.381	0.355		0.211	0.369	0.420	
	st. dev.	0.289	0.276	0.305		0.271	0.247	0.299	
4	*mean*	0.457	0.251	0.293		0.432	0.232	0.333	
	st. dev.	0.354	0.255	0.301		0.360	0.253	0.315	
5	*mean*	0.421	0.238	0.338		0.392	0.234	0.376	
	st. dev.	0.323	0.234	0.293		0.329	0.233	0.299	
6	*mean*	0.454	0.217	0.323		0.440	0.189	0.367	
	st. dev.	0.346	0.250	0.308		0.367	0.241	0.328	
7	*mean*	0.307	0.443	0.240		0.289	0.435	0.276	
	st. dev.	0.315	0.321	0.301		0.303	0.304	0.315	
8	*mean*	0.344	0.434	0.227		0.316	0.396	0.289	
	st. dev.	0.303	0.294	0.292		0.308	0.261	0.305	
9	*mean*	0.340	0.429	0.231		0.329	0.411	0.262	
	st. dev.	0.318	0.321	0.316		0.332	0.332	0.342	

Notes: For each choice problem and each group of observations (4-commodities and 3-commodities), the table reports the mean budget shares ('mean') over all participants (individuals and dyads), together with the corresponding standard deviations ('st.dev.').

4. Test results

4.1. Individual rationality tests

We first regard test results for individual rationality. Table 3 reports on the individuals that violate the $GARP$ condition discussed in Section 2.1; it gives the number of individuals violating $GARP$ as well as some descriptive statistics for the distribution of the Afriat efficiency index values (see (2.3)) for those $GARP$ violating individuals. We find that less than 10 percent of all individuals (5 out of 104 individuals in the 4-commodities condition and 8 out of 102 in the 3-commodities condition) violate the nonparametric individual rationality condition. Still, we also find that some individuals quite severely violate the $GARP$ condition; see the minimal Afriat index values of 0.36 for the 4-commodities group and 0.48 for the 3-commodities group. But, given the small fraction of violations, these may safely be regarded as accidental outliers.

To gain some further insight into the goodness-of-fit of the individual rationality model, Table 4 shows the distribution of the number of *GARP* violations (i.e. the number of observations j with $\theta^j < 1$ in (2.2)), again for the 4-commodities group and the 3-commodities group separately. Table 4 tells us whether the results in Table 3 are driven by many or by a few violations for the *GARP* violating individuals. We find that all but one *GARP* violating individual have no more than 4 observed consumption choices that are inconsistent with this (observation-specific) rationality condition. One individual (in the 4-commodities group) exhibits no less than 8 observed choices that are inconsistent with *GARP*. But, again, this can reasonably be considered as a casual outlier.

As a further base of comparison, we also include the distribution of violations corresponding to random behavior; see the columns '4-commodities (bootstrap)' and '3-commodities (bootstrap)' in Table 4. Random behavior is modeled using the bootstrap method for panel data as described by Andreoni and Miller (2002) and applied by Harbaugh, Krause and Berry (2001) within a similar experimental context.[12] The method essentially mimics random behavior for each price regime (or budget) by drawing randomly from the observed set of choices under that price regime (e.g. our experiment observes 104 choices for the 4-commodities group and 102 choices for the 3-commodities group, under 9 different price regimes). This gives information on the expected distribution of violations under random choice, while incorporating information on the participants' actual choices. All bootstrap results reported in this paper (including those in Table 4) are based on Monte Carlo-type simulations that include approximately 50000 iterations.

On the basis of Table 4 we conclude that random behavior would yield a distribution of *GARP* violations that significantly differs from the one that is actually observed. For example, random behavior as described above would yield *GARP* consistency only in approximately 18 percent of the cases for both the 4-commodities and the 3-commodities group, as compared to no less than respectively 95 percent and 92 percent *GARP* consistencies in the observed choices. We may also interpret that the *GARP* test has a power (i.e. a probability of detecting the random behavior) of about 82 percent for both groups. In fact, random behavior entails a substantially higher probability mass for any positive number of *GARP* violations; and the relative difference with the observed distribution generally increases for larger numbers of violations.[13]

Generally, we conclude that the individual rationality model is strongly supported for our specific choice setting. The next question is to what extent the collective decisions, which are taken under the same 9 price regimes, are effectively consistent with collective rationality as modeled in Section 2.2. And, if consistent with the general collective model, to what extent do these collective choices correspond to the parsimonious egoistic rationality model? These are the questions that we discuss next.

[12] This bootstrap method is similar to the randomization method proposed by Bronars (1987), which has also been used frequently in the literature. The mere difference is that 'random' choices (for each price regime) are drawn from the observed distribution whereas Bronars randomly draws from the uniform distribution (which may significantly differ from the observed distribution). We refer to Andreoni and Harbaugh (2006) for a detailed discussion of the strengths and weaknesses of alternative randomization procedures, and corresponding power measures, that have been used within a nonparametric context.

[13] In Section 4.2, we use an alternative bootstrap procedure for calculating the power of the sufficiency condition in Proposition 2. For compactness, we have not included the results of this alternative procedure for the individual rationality test. Still, it is worth indicating that this alternative procedure obtained even more favorable power results for our individual rationality test. [A similar remark holds for the egoistic rationality results in Table 5.]

Table 3: individual rationality; GARP violations - Afriat efficiency indices; descriptive statistics

	4-commodities (104)	*3-commodities (102)*
number	5	8
maximum	0.990	0.990
3rd quartile	0.987	0.977
median	0.800	0.966
1st quartile	0.722	0.942
minimum	0.360	0.475

Notes: For each group of observations (4-commodities and 3-commodities) the total number of evaluated individuals is reported between brackets; 'number' stands for the number of individuals violating GARP. Descriptive statistics (maximum, 3rd quartile, median, 1st quartile and minimum) pertain to the distribution of the Afriat efficiency index as defined over the subgroups of GARP violating individuals.

Table 4: individual rationality; distribution of GARP violations

	percentage of group with violations			
GARP violations	*4-comm. (104)*	*3-comm. (102)*	*4-comm. (bootstrap)*	*3-comm. (bootstrap)*
0	95.2	92.2	18.2	18.1
1	1.0	2.9	5.5	2.4
2	1.0	3.9	17.2	18.6
3	1.0	0.0	13.1	11.7
4	1.0	1.0	13.3	13.5
5	0.0	0.0	11.9	12.5
6	0.0	0.0	9.5	10.4
7	0.0	0.0	6.3	7.0
8	1.0	0.0	3.6	4.1
9	0.0	0.0	1.4	1.6

Notes: For each group of observations (4-commodities and 3-commodities) the total number of evaluated individuals is reported between brackets. The column 'GARP violations' stands for the number of GARP violations (ranging from minimally 0 to maximally 9). For each group (4-commodities and 3-commodities), the table reports the percentage of (observed and random/'bootstrap') choices corresponding to different numbers of violations.

4.2. Collective rationality tests

We first regard data consistency with the general collective consumption model. In doing so, we restrict attention to those dyads for which both members act consistent with the individual rationality test, which obtains 47 dyads (94 individuals) for the 4-commodities group and 43 dyads (86 individuals) for the 3-commodities group.[14] The corresponding dyads' decisions are all fully consistent with the general collective rationality condition in Proposition 1. Specifically, we find that all but one of the dyads are consistent with the sufficient condition in Proposition 2. The Appendix proves consistency with the collective rationality condition for the remaining one dyad (from the 4-commodities group) that is inconsistent with the sufficiency condition: it presents a specification of personalized prices and quantities that makes the dyad's observed behavior obey the necessary and sufficient condition in Proposition 1.[15]

[14] We note that excluding the couples with 'irrational' individuals in this way does not affect our main qualitative conclusions. Still, because individual rationality is a prerequisite for collective rationality, we find it logically consistent to focus our discussion on couples with rational singles. A slightly different approach is followed in Section 4.3, when we regard alternative efficiency criteria that allow for (small) deviations from 'exactly' rational behavior (as captured by the Afriat efficiency index). See our discussion of Table 9.

[15] We may contrast these test results with those obtained for the individual rationality *GARP* condition in Definition 2 when applied to couples; this actually provides a test for the so-called 'unitary model', which

We also regard the power of the sufficiency condition in Proposition 2; this power estimate can be interpreted as an upper bound for the power of the necessary and sufficient condition in Proposition 1. To do so, we employ a similar randomization procedure as for the individual rationality test: for each price regime we randomly draw consumption choices from the set of observed dyads' choices (47 for the 4-commodities group and 43 for the 3-commodities group). The resulting power estimate equals 4.6 percent for the 4-commodities case and 5.0 percent for the 3-commodities case. While these figures are effectively above the percentage of violations that is actually observed (namely 1/47 percent for the 4-commodities case and zero percent for the 3-commodities case), they are far too low for convincingly supporting the collective rationality hypothesis.

At this point, it is worth indicating that the randomization procedure that is used for computing the power may be subject to criticism; it puts a lot of prior structure on the so-called 'random' choices by conditioning their selection on the price regime. An alternative randomization procedure does not consider the specific price regime, but considers the *full* set of all actually observed budget allocations (i.e. relative budget shares) as potentially 'random' choices for *every* price regime. For our application, this implies for each price regime 9×47 possible choices for the 4-commodities case and 9×43 possible choices for the 3-commodities case. This alternative procedure obtains a power estimate for the sufficiency test that equals 15.3 percent for the 4-commodities group and 13.2 percent for the 3-commodities group. While these estimates are obviously more favorable for the collective rationality test, one may still argue that they again do not as such convincingly support collective rationality.

A much stronger case can be expected from the egoistic rationality model as a special case of the collective rationality model: this model puts much more *a priori* structure on the collective decision process. As discussed in Section 2, the fact that our experiment fully recovers the personalized quantities allows for testing a necessary and sufficient condition for such egoistic rationality, which essentially consists of two *GARP* tests per dyad, i.e. one for each individual member (see Corollary 1). Moreover, consistency of the collective decisions with the 'rudimentary' egoistic model should not be counter-intuitive for the unsophisticated decision setting under study: it may well be that none of the commodities taken up in the experiment is associated with consumption externalities; and (for the 4-commodities group) the cashed amount, which does allow for public consumption, should of course not necessarily be used for such public consumption.

Table 5 has a similar interpretation as Table 3, but now pertains to egoistic rationality; it gives information on violations of the corresponding *GARP* conditions at the level of the individual dyads' members. Although we do have (in relative terms) slightly more violations of egoistic rationality than of individual rationality, we likewise find that less than ten percent of all observations (9 out of 94 individual members for the 4-commodities case and 8 out of 86 members for 3-commodities case) is inconsistent with the collective rationality condition.[16] The other descriptive statistics confirm this close similarity between the egoistic rationality results and the individual rationality results (in Table 3).

Table 6 gives the corresponding distribution of the number of (egoistic rationality) *GARP*

describes group behavior as if the group consists of a single decision maker (i.e. the group maximizes a single utility function). We find that about 10 percent of the dyads in the 3-commodities group and about 7 percent of the dyads in the 4-commodities group violate the (unitary) *GARP* condition. This shows that the general collective model allows for rationalizing unitary irrationalities. In this respect, it is also worth recalling the solid conceptual basis of the collective approach (e.g. in the context of welfare analysis), which -of course- does not hold for the traditional unitary approach. As indicated in the Introduction, its conceptual appeal forms a prime motivation for our focus on the collective consumption model.

[16] Of course, *stricto sensu* consistency with the egoistic model (see Corollary 1) requires that both individual members simultaneously meet the corresponding *GARP* condition. When using that criterion we find that 39 out of 47 dyads (83 percent) in the 4-commodities group and 37 out of 43 dyads (86 percent) in the 3-commodities group behave egoistically rational. See also our following discussion of Table 9.

violations. Once more, we find that these results (for both the 4-commodities group and the 3-commodities group) are largely similar to those for individual rationality (see Table 5), which provides further support for the (*in casu* egoistic) collective rationality model. For example, no individual member exhibits more than three *GARP* violations.

The table also gives the distribution of the *GARP* violations under random behavior. To obtain these results, we use a similar randomization procedure as for computing the results in Table 4. But in this case we exploit the two-step budgeting interpretation of the egoistic model; see our discussion leading up to the decision problem (2.8) for each individual dyad member. This two-step structure also underlies our bootstrap procedure for constructing random choices: for each price regime, we randomly select the income share for each individual member from the observed distribution; and, subsequently, we randomly select the budget allocation (i.e. the relative budget shares), again drawing from the observed distribution corresponding to the given price regime. The bootstrap distributions in Table 6 (for the 4-commodities and the 3-commodities group) are based on 50000 such random choices for the 9 price regimes. We find that this distribution is very different from the one that is observed. The corresponding power estimates amount to about 76 percent for the 4-commodities group and 72 percent for the 3-commodities group. While slightly below the power of the individual rationality test (see Table 4), the distribution of *GARP* violations for the observed choice behavior (including the observed proportion of *GARP* inconsistencies) is sufficiently different from that corresponding to random behavior to safely conclude strong support of the egoistic rationality model.

As a general conclusion we can state that our results provide convincing support for the collective rationality model, which here takes the form of the parsimonious (and therefore powerful) egoistic rationality model; our empirical results provide quasi-equally strong support for this model as for the individual rationality model. Conveniently, the fact that this 'rudimentary' version of the collective decision model adequately describes most of the observed behavior in our experiment seems intuitively reasonable given the simple choice setting at hand. Still, it also seems interesting to consider in somewhat more detail the about 10 percent observations that are inconsistent with this egoistic model while consistent with the (albeit less powerful) general collective consumption model. A natural next question is whether these violations of egoistic rationality may be interpreted in terms of consumption externalities and/or public consumption.[17] This forms the subject of the next section.

Table 5: egoistic rationality; GARP violations - Afriat efficiency indices; descriptive statistics

	4-commodities (94)	*3-commodities (86)*
number	9	8
maximum	0.991	0.999
3rd quartile	0.986	0.997
median	0.944	0.980
1st quartile	0.550	0.958
minimum	0.521	0.925

Notes: For each group of observations (4-commodities and 3-commodities) the total number of evaluated individual members is reported between brackets; 'number' stands for the number of individual members violating GARP corresponding with egoistic rationality. Descriptive statistics (maximum, 3rd quartile, median, 1st quartile and minimum) pertain to the distribution of the Afriat efficiency index as defined over the subgroups of GARP violating individual members.

[17] In this respect, it is worth recalling that the results in Tables 5 and 6 pertain to dyads for which both individuals act consistent with the individual rationality test. This makes it particularly interesting to 'rationalize' (in terms of consumption externalities and public consumption) the egoistic irrationality of these dyads.

Table 6: egoistic rationality; distribution of GARP violations

	percentage of group with violations			
GARP violations	*4-comm. (94)*	*3-comm. (86)*	*4-comm. (bootstrap)*	*3-comm. (bootstrap)*
0	90.4	90.7	24.1	21.9
1	1.1	0.0	1.7	0.4
2	6.4	9.3	18.5	17.7
3	2.1	0.0	11.0	10.4
4	0.0	0.0	12.8	12.7
5	0.0	0.0	11.3	11.6
6	0.0	0.0	9.3	10.5
7	0.0	0.0	6.4	7.7
8	0.0	0.0	3.6	5.0
9	0.0	0.0	1.4	2.2

Notes: For each group of observations (4-commodities and 3-commodities) the total number of evaluated individual members is reported between brackets. The column 'GARP violations' stands for the number of GARP violations corresponding with the egoistic rationality model (ranging from minimally 0 to maximally 9). For each group (4-commodities and 3-commodities), the table reports the percentage of (observed and bootstrap) choices corresponding to different numbers of violations.

4.3. 'Rationalizing' egoistic irrationality

To 'rationalize' the egoistically irrational dyads in terms of consumption externalities and public consumption, we will regard in more detail the egoistic rationality violations of the 4-commodities group and of the 3-commodities group. In addition, recalling our discussion of the experimental design in Section 3, we use the distinction between four different types of dyads, namely *friends (m-m)*, *friends (f-f)*, *friends (f-m)* and *partners (f-m)*.

We first regard consumption externalities (or altruism). As explained before, we can exclude public consumption for the 3-commodities group, which implies that the egoistic rationality test effectively boils down to testing for the presence of such externalities. Given this, we regard the lower panel of Table 7, which has a similar structure as Table 5 but now presents the results for the four dyad types under investigation. Table 8 similarly decomposes the aggregate (4-commodities and 3-commodities) results in Table 6. According to the results in these tables, 'altruistic' decision makers (who account for consumption externalities in their consumption decisions) seem to be situated in dyads containing two friends with at least one female member (i.e. the types *friends (f-m)* and *friends (f-f)*). Interestingly, this result falls in line with existing evidence that females are more altruistic towards friends and other close individuals than males (see e.g. the meta-analysis of Eagly and Crowley, 1986; Croson and Gneezy, 2005, provide a recent review of studies on gender differences in preferences).[18] In that interpretation, the observation that all dyads of the category *partners (f-m)* in the 3-commodities group are consistent with egoistic rationality may seem paradoxical. Still, this last result might be explained by the fact that for these dyads the consumption decisions in our experiment (for a joint budget of € 10) account for only a small proportion of the total joint budget on which the partners have to decide collectively; and thus consumption externalities (altruism) may well affect other ('more important') collective choices not taken up in this experiment. Of course, the evidence in Table 7 is far too weak for drawing robust conclusions; see the small number of violations of the egoistic rationality conditions, and the high Afriat efficiency index values (with overall minimum =

[18] In this respect, it is also interesting to note that our results on the sharing rule (see Section 3) seem to comply with existing evidence that females propose equal split more than males (see Corson and Gneezy, 2005, for a survey of results). For example, an equal split of the income under all 9 price regimes, when using the specification of personalized prices that applies under egoistic rationality, is used by no less than 37.5 percent of all dyads in the category *friends (f-f)* and 33.33 percent of all dyads in the category *friends (f-m),* as opposed to only 13.0 percent of all dyads in the category *friends (m-m)* and 12.0 percent of all dyads in the category *partners (f-m).* In our opinion, a detailed investigation of these sharing rule mechanics may constitute yet another interesting research avenue in which the nonparametric collective rationality testing tools can be instrumental.

0.925). Although these results should be interpreted as indicative rather than conclusive, they do suggest the nonparametric collective rationality tests proposed in this paper as potentially useful tools for investigating this type of questions; specially targeted experiments may help to further investigate the observed patterns in greater detail.

Let us then consider the possibility of public consumption. As indicated in Section 3, public consumption is possible for the 4-commodities group and not for the 3-commodities group. Therefore, comparing the violations of egoistic rationality for the 4-commodities group with those for the 3-commodities group may reveal whether or not public consumption is relevant within our choice setting. Again, we make the distinction between the four dyad types. Comparison of the upper and lower panels of Tables 7 and 8 indeed seems to confirm that violation of the egoistic rationality model may be rationalized through public consumption, thus suggesting that such public consumption is a relevant dimension of collective decision making even for unsophisticated choice settings. Specifically, recall that our results for the 3-commodities group suggest the absence of consumption externalities for the dyad types *friends (m-m)* and *partners (f-m)* in the simple choice setting of our experiment. Under that maintained assumption, public consumption may explain the observed violations of collective rationality for the 4-commodities group. As for the other categories *friends (f-m)* and *friends (f-f)*, because we did observe violations of egoistic rationality in the 3-commodities condition, we cannot distinguish between consumption externalities and public consumption in the 4-commodities condition. Still, we do find that the violations of egoistic rationality are more severe when public consumption is possible; see in particular the changes of the descriptive statistics of the Afriat efficiency index for these two dyad types. Once more, we should stress that the current set-up only allows for tentative conclusions.

So far we have considered egoistic rationality tests at the level of the individual dyad members. Of course, collective rationality and thus also egoistic rationality should actually be considered at the dyad level: a dyad behaves egoistically rational only if both individual members *simultaneously* meet the corresponding *GARP* condition. Our final Table 9 reports such dyad level egoistic rationality results. Specifically, it gives the number of dyad observations and the percentage of so-called 'egoistically rational' dyads (again subdivided by type) for alternative criteria expressed in terms of the Afriat efficiency index (2.7): each $X\%$ efficiency criterion ($X = 100$, 99 or 95) states that a dyad is $X\%$ egoistically rational if the corresponding Afriat efficiency index is at least $X\%$ (e.g. the earlier results in Tables 7-8 comply with the 100% efficiency criterion).[19] Varian (1990) suggested a similar efficiency criterion for individual rationality, and he proposed the 95% cut-off level. We apply the idea for collective rationality, and additionally consider the 100% and 99% cut-off levels.

The results in Table 9 support the same (tentative) conclusions as before. From the 3-commodities results, we may derive that altruism helps in explaining violations of egoistic rationality for dyads of the types *friends (f-f)* and *friends (f-m)*. For example, we find that only 63.6 (75, 92.3) percent dyads of the type *friends (f-f)* are consistent with the 100% (99%, 95%) egoistic rationality criterion. A similar, albeit less strongly marked, result also applies to the category *friends (f-m)*. In addition, comparison of the 3-commodities results and the 4-commodities results indicates that public consumption can rationalize egoistically irrational behavior of, most notably, dyads of the types *friends (m-m)* and *partners (f-m)*. For example, while 100 percent dyads of the type *friends (m-m)* are consistent with egoistic rationality in the 3-commodities condition (for all three efficiency criteria), only 78.6 (85.7, 92.9) percent is consistent with the 100% (99%, 95%) egoistic rationality criterion in the 4-commodities condition. Similar differences, albeit to a somewhat lesser extent, hold for the category *partners (f-m)*.

In conclusion, our findings suggest that both consumption externalities and public consump-

[19] To be exact, each $X\%$ efficiency criterion only considers dyad observations for which each *individual* dyad member passes the similarly defined $X\%$ efficiency criterion defined in terms of the Afriat efficiency index (2.3) *for individuals*. This makes that the number of dyad observations increases for lower X.

tion are relevant for modeling (even simple) collective decision settings. In addition, they seem to reveal that the appropriate specification of the collective consumption model may depend on the specific dyad type in combination with the specific decision problem at hand (e.g. including the possibility of public consumption or not).

Table 7: egoistic rationality; GARP violations - Afriat efficiency indices; descriptive statistics per type

4-commodities	*partners (f-m) (26)*	*friends (f-m) (22)*	*friends (f-f) (18)*	*friends (m-m) (28)*
number	1	2	3	3
maximum	0.944	0.984	0.990	0.991
3rd quartile	0.944	0.868	0.770	0.989
median	0.944	0.752	0.550	0.986
1st quartile	0.944	0.636	0.550	0.918
minimum	0.944	0.521	0.550	0.851
3-commodities	*partners (f-m) (22)*	*friends (f-m) (24)*	*friends (f-f) (22)*	*friends (m-m) (18)*
number	0	3	5	0
maximum	-	0.996	0.999	-
3rd quartile	-	0.961	0.998	-
median	-	0.925	0.980	-
1st quartile	-	0.925	0.980	-
minimum	-	0.925	0.969	-

Notes: For each group of observations (4-commodities and 3-commodities; four dyad types) the total number of evaluated individual members is reported between brackets; 'number' stands for the number of individual members violating GARP corresponding with egoistic rationality. Descriptive statistics (maximum, 3rd quartile, median, 1st quartile and minimum) pertain to the distribution of the Afriat efficiency index as defined over the subgroups of GARP violating individual members.

Table 8: egoistic rationality; distribution of GARP violations per type

	percentage of group with violations (4-commodities)			
GARP violations	*partners (f-m) (26)*	*friends (f-m) (22)*	*friends (f-f) (18)*	*friends (m-m) (28)*
0	96.2	90.9	83.3	89.3
1	0.0	0.0	0.0	3.6
2	3.8	9.1	5.6	7.1
3	0.0	0.0	11.1	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
	percentage of group with violations (3-commodities)			
GARP violations	*partners (f-m) (22)*	*friends (f-m) (24)*	*friends (f-f) (22)*	*friends (m-m) (18)*
0	100.0	87.5	77.3	100.0
1	0.0	0.0	0.0	0.0
2	0.0	12.5	22.7	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0

Notes: For each group of observations (4-commodities and 3-commodities; four dyad types) the total number of evaluated individual members is reported between brackets. The column 'GARP violations' stands for the number of GARP violations corresponding with the egoistic rationality model (ranging from minimally 0 to maximally 9). For each group, the table reports the percentage of observed choices corresponding to different numbers of violations.

Table 9: egoistic rationality at the dyad level; alternative efficiency criteria; per type

	100% efficiency criterion			**99% efficiency criterion**			**95% efficiency criterion**		
	all	*4-comm.*	*3-comm.*	*all*	*4-comm.*	*3-comm.*	*all*	*4-comm.*	*3-comm.*
all types									
number	90	47	43	92	48	44	98	49	49
% pass test	84.4	83.0	86.0	89.1	87.5	90.9	93.9	91.8	95.9
partners (f-m)									
number	24	13	11	25	14	11	26	15	11
% pass test	95.8	92.3	100.0	96.0	92.9	100.0	96.2	93.3	100.0
friends (f-m)									
number	23	11	12	23	11	12	24	11	13
% pass test	82.6	81.8	83.3	87.0	81.8	91.7	91.7	90.9	92.3
friends (f-f)									
number	20	9	11	21	9	12	22	9	13
% pass test	70.0	77.8	63.6	81.0	88.9	75.0	90.9	88.9	92.3
friends (m-m)									
number	23	14	9	23	14	9	26	14	12
% pass test	87.0	78.6	100.0	91.3	85.7	100.0	96.2	92.9	100.0

Notes: For each group of observations (4-commodities and 3-commodities; four dyad types) the table reports the efficiency results according to alternative X% efficiency criteria (X = 100, 99, 95). For a given X the row 'number' gives the number of dyad observations with an Afriat efficiency index (2.3) of at least X% for each individual member; and the row '% pass test' gives the percentage of such dyad observations with an Afriat efficiency index (2.7) of at least X%.

5. Summary and concluding remarks

We have provided a first nonparametric-experimental test of the collective consumption model. We find that all observed dyad behavior is consistent with the nonparametric conditions that correspond to the general collective consumption model, which incorporates the possibility of consumption externalities and public consumption. In addition, our collective choice data provide a (nearly) equally strong case for egoistic rationality (excluding consumption externalities and public consumption) as our individual choice data do for individual rationality: a large proportion of dyads (i.e. above 90 percent) is effectively consistent with the (powerful) egoistic rationality conditions. We believe that the intuition for this result lies in the specific (unsophisticated) choice setting of our experiment; which suggests that the egoistic model may be useful for describing collective choice behavior in simple consumption decision settings. Finally, we have argued that egoistically irrational choice data can be rationalized in terms of consumption externalities and public consumption: e.g. in particular female friends seem to behave altruistically, which corresponds to consumption externalities; and some dyads effectively seem to use (even fairly small) amounts of cash for public consumption. Admittedly, although these rationalization arguments have intuitive appeal, they can at best be interpreted as tentative, mainly because of the small number of such egoistically irrational dyads in our experiment. Still, in our opinion they do at least suggest that the appropriate model specification depends on the specific dyad type (e.g. friends or partners; gender composition) and choice setting (e.g. including the possibility of public consumption) at hand.

At a more general level, we believe that this first test demonstrates that the nonparametric (collective consumption) analysis of experimental data can be particularly useful for gaining insight in the mechanics of group decision making under alternative choice conditions. For example, follow-up research can focus on experimental choice settings that are specifically designed for studying the specificities that cause consumption externalities (or altruism) and public consumption; this complements the existing literature that focuses on altruism in individual decision making (e.g. Andreoni and Miller, 2002). In addition, it may concentrate on the bargaining idea (including the determinants of the bargaining power) that underlies the collective consumption model. Alternatively, whereas this first study restricted attention to dyads, future research may investigate group decisions that involve more than two decision makers. In such settings, one may e.g. be interested in the number of decision makers that are effectively involved in the group decision process. That is, how many decision makers have to be accounted for in order to make the observed group behavior consistent with collective rationality? In a family context, a closely related research question is whether and to what extent children bear on the bargaining process or do have actual bargaining power within households. [We could not address this question in our own experiment because participants were undergraduate students without children.] Or, further extending the results of Harbaugh, Krause and Berry (2001) on the individual rationality of young children, one can study the group decision behavior of young children, including the nature of the underlying preferences (egoistic or altruistic). Specially targeted experiments that use the nonparametric collective rationality tests may enhance our understanding of these issues.

Another general conclusion of our study pertains to the specification of the rationality tests themselves. In particular, our comparison of the general collective rationality results with the egoistic rationality results shows that knowledge of personalized quantities and prices (which in our case were fully observed under egoistic rationality) may dramatically increase the power of the tests. From a practical perspective, more powerful tests obviously imply more powerful recovery and forecasting results. [See Varian (1982, 2006) for surveys of nonparametric recovery and forecasting tools that build on the *GARP* test for individual rationality; these tools could be adapted to the collective consumption context.] This pleads for developing collective consumption data sets that incorporate such personalized quantity and price information; such detailed data sets seem especially valuable given the good fit of the collective consumption model.

Two final remarks are in order with respect to increasing the power of the nonparametric tests in practical applications. First, it is clear that, if we knew the individual members' orderings of the (collectively chosen) consumption bundles, then we could design more powerful tests of collectively rational behavior. Such tests would have a formally similar structure as the tests that apply in a production setting (where the observed outputs reveal the ordering information); see Cherchye, De Rock and Vermeulen (2006) for the corresponding tests of cost minimizing production behavior that equally account for (*in casu* production) externalities and joint consumption (*in casu* of inputs). Within experimental set-ups it is actually possible to directly ask the participants for the ordering information; this suggests an interesting exercise for follow-up research. Second, the power of the nonparametric tests may be increased by extending the existing tests to include the 'sequential maximum power path' idea of Blundell, Browning and Crawford (2003), who originally focused on the *GARP* condition for individual rationality. Such an extension could render the nonparametric toolkit for the collective model, which effectively seems to provide an adequate description of the observed group decision behavior, particularly useful for addressing real-life research questions (such as the prediction of group behavior in new situations and/or welfare analysis).

Appendix

We provide a collective rationalization in terms of the nonparametric conditions in Proposition 1 for the one dyad observation that does not meet the sufficiency condition in Proposition 2. Table A1 reports the observed aggregate (dyad level) quantities and the corresponding (member level) personalized quantities for this dyad. Combining the aggregate quantity information with the price information in Table 1 (and using that the price of cash equals 1), it can be verified that this dyad does not meet the sufficiency condition. Specifically, we have for the three choice observations 2, 3 and 5 that for each pair $i, j \in \{2, 3, 5\} : \mathbf{p}_i'\mathbf{q}_i > \mathbf{p}_i'\mathbf{q}_j$ and $\mathbf{p}_j'\mathbf{q}_j > \mathbf{p}_j'\mathbf{q}_i$. In such a case there does not exist a partitioning of the observed set S (of aggregate quantities and prices) that distributes these three observations over two subsets S_1 and S_2 so that each individual subset meets the corresponding *GARP* condition.

Still, the dyad does meet the necessary and sufficient condition in Proposition 1. For example, Table A2 gives a feasible specification of the personalized prices for which such consistency can be verified: assuming that the cashed amounts are pooled to spend on a publicly consumed good ('public good', with an aggregate price of unity), both dyad members simultaneously meet the corresponding *GARP* conditions in terms of the personalized quantities (for the goods wine, orange juice and M&Ms) in Table A1 and the corresponding personalized prices in Table A2. Of course, such a data rationalizing specification of the personalized prices should in general not be unique; alternative specifications can obtain the same consistency result (e.g.: our interpretation of cashed amounts in terms of public consumption is not necessary for establishing the consistency).

Table A1: aggregate and personalized quantities for the 9 choice problems

Choice problem	Wine	Orange juice	MMs	Saving
		aggregate quantities		
1	75	50	200	0
2	75	0	100	200
3	75	50	75	100
4	450	0	0	550
5	0	50	100	300
6	450	0	100	250
7	0	400	0	600
8	225	112	0	100
9	100	600	0	100
		personalized quantities member 1		
1	37.5	25	100	0
2	37.5	0	50	100
3	37.5	25	37.5	50
4	225	0	0	275
5	0	25	50	150
6	225	0	50	125
7	0	200	0	300
8	112.5	56	0	0
9	50	300	0	50
		personalized quantities members 2		
1	37.5	25	100	0
2	37.5	0	50	100
3	37.5	25	37.5	50
4	225	0	0	275
5	0	25	50	150
6	225	0	50	125
7	0	200	0	300
8	112.5	56	0	100
9	50	300	0	50

Notes: Consumption quantities are expressed in terms of the same commodity units as the prices in Table 1: a unit of red wine is 1 centiliter, a unit of orange juice is 3 centiliters, and a unit of M&Ms is 5 grams.

Table A2: collectively rationalizing personalized prices for the 9 choice problems

Choice problem	Wine	Orange juice	MMs	Wine	Orange juice	MMs	Public good
	personalized prices member 1 own (= member 1) consumption			*personalized prices member 1 other (= member 2) consumption*			*personalized price member 1*
1	8	4	1	8	4	1	0.5
2	8	3	2	8	3	2	0.5
3	9	3	1	9	3	1	0.5
4	1	8	4	1	8	4	0.5
5	0	0	0	0	0	0	0.5
6	1	9	3	1	9	3	0.5
7	4	1	8	4	1	8	0.5
8	3	2	8	3	2	8	0
9	3	1	9	3	1	9	0.5
	personalized prices member 2 other (= member 1) consumption			*personalized prices member 2 own (= member 2) consumption*			*personalized price member 2*
1	0	0	0	0	0	0	0.5
2	0	0	0	0	0	0	0.5
3	0	0	0	0	0	0	0.5
4	0	0	0	0	0	0	0.5
5	2	8	3	2	8	3	0.5
6	0	0	0	0	0	0	0.5
7	0	0	0	0	0	0	0.5
8	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0.5

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