

Measuring the willingness-to-pay for others’ consumption: An application to joint decisions of children.*

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Abstract

We propose a method to quantify other-regarding preferences in group decisions. Our method is based on revealed preference theory. It measures willingness-to-pay for others’ consumption and willingness-to-pay for equality in consumption by evaluating consumption externalities in monetary terms. We introduce an altruism parameter and an inequality aversion parameter. Each parameter defines a continuum of models characterized by varying degrees of externalities. We study the empirical performance of our method through a simulation analysis, in which we also investigate the impact of measurement error and increased sample size. Finally, we use our method to analyze decisions made by dyads of children in an experimental setting. We find that children’s decisions are particularly characterized by varying levels of altruism. We relate this heterogeneity across children to age, gender and the degree of friendship in dyads.

JEL Classification: D11, D12, C14

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1 Introduction

This study is motivated by Rabin (2013)’s “PEEMs” (Portable Extensions of Existing Models) research program, which aims at developing tractable refinements of existing economic models that integrate psychological insights. The program encourages the design of new models that encompass a basic, pre-existing model at one particular parameter value, while other values for the same parameter imply modifications of the basic model. Rabin recommends the modeling of social preferences as a prime PEEMish application area. The literature has produced a mass of experimental evidence that rejects the standard model of purely selfish behavior. However, Rabin argues that the replacing models with social preferences typically fail to derive plausible economic implications beyond specific laboratory environments. This indicates a need for analytical tools to handle non-selfish preferences in more general settings.

In the current paper, we apply Rabin’s PEEM program to two main types of social preferences (other types of social preferences are discussed in the concluding section). We consider the role of altruism and inequality aversion in group consumption behavior. In the case of group consumption, these extensions imply that individuals are not purely selfish, but willing to pay for *others’ consumption* and for *equality of consumption*. We introduce a methodology that allows us to measure this revealed willingness-to-pay in monetary terms. In line with our above motivation, the methodology to deal with altruistic behavior associates an altruism parameter value of zero with the standard model of purely selfish consumers, but also includes a whole range of other models (with varying levels of altruism) for higher parameter values. Similarly, the methodology to deal with inequality aversion associates an inequality aversion parameter value of zero with the selfish model, but also encompasses a whole range of other models (with varying preferences for equality) for higher parameter values. In this way, we consider two distinct generalizations – with social preferences – of the selfish consumption model.

In the empirical part of our paper, we first investigate the performance of our revealed preference method through a simulation analysis. Specifically, we study the goodness of our altruism and inequality aversion estimates in a simulated setting that uses a particular parametrization of the individual preferences and the intra-group decision process. In doing so, we also assess the impact of measurement error and increased sample size (yielding additional price variation).

Subsequently, we use our methodology to analyze the consumption choices made by dyads (i.e. two-person groups) of children in a tailored experiment. As we discuss in detail further on, there is quite some debate in the literature on how (non-)selfish behavior corresponds to specific child characteristics. In our application, we first investigate to what extent children’s consumption decisions are effectively characterized by externalities (i.e. altruism or inequality aversion). It will turn out that particularly altruism helps to rationalize the observed consumption behavior. Subsequently, we examine how age, gender and friendship between dyad members relate to revealed altruism, so adding useful empirical input to the existing debate. At a more general level, this application shows the practical usefulness of our method to analyze the presence and determinants of prosocial (i.e. non-selfish) consumer behavior.

The remainder of this introductory section specifies our research question. We also introduce the basic framework of our measurement methodology, and motivate our empirical

application.

Prosocial behavior. Consumer preferences are characterized by externalities when individual utilities depend not only on the own material consumption but also on the others' consumption. In the empirical literature there is plenty of evidence that economic agents often act non-selfishly. For example, in social dilemma games, experimenters find that subjects cooperate even in one-shot games, when the only rational choice under selfishness is to defect; in ultimatum games subjects offer a substantial amount of tokens to their counter-parties; in dictator games the dictators often share a fraction of their budget. The literature has suggested many alternative explanations for these phenomena, including altruism (Andreoni and Miller (2002), Fisman et al. (2007) and Cox et al. (2008)), inequality aversion (Fehr and Schmidt (1999) and Bolton and Ockenfels (2000)), reciprocity (Charness and Rabin (2002)) and concerns for efficiency and the pay-offs of the least well off (Charness and Rabin (2002) and Engelmann and Strobel (2004)).

In the current paper, our focus is on two types of social preferences that are typically related to the notion of prosocial behavior: altruism and inequality aversion. We aim at measuring the degree of prosocial behavior in a general setting of group consumption. To do so, we assume a structural model of rational group behavior, which allows for consumption externalities, and which enables us to quantify the monetary value of externalities as individuals' willingness-to-pay for others' consumption and individuals' willingness-to-pay for equality of consumption. In particular, we can check how large this willingness-to-pay needs to be in order to rationalize the observed group consumption decisions. This methodology has several useful applications. For example, it can be used to quantify the extent to which models with selfish consumers are "wrong" and, therefore, may lead to biased conclusions. Also, as we will illustrate in our own application, it allows us to relate the degree of prosocial behavior to specific consumer characteristics, which in turn leads to identifying which type of consumer is generally more or less selfish.

At this point, we want to remark that the literature studying joint or interdependent decision making has tended to merge the two motives (altruism and inequality aversion). Illustrative is that the most influential measurement method in psychology, the Social Value Orientation explicitly merges the two motives into the so-called "prosocial type" (van Lange (1999)). The small proportion of pure types (altruistic and inequality averse) that recent research in psychology (Millet and Dewitte (2007) and Murphy et al. (2011)) and economics (Fehr et al. (2013)) reported, supports the idea that these two prosocial motives tend to co-occur. Our method allows us to separately investigate the implications of the two types of prosocial behavior for group consumption decisions.

Measuring externalities. We assume the cooperative model as our structural model of group consumption (with and without selfish preferences). This consumption model was originally proposed by Apps and Rees (1988) and Chiappori (1988, 1992), and is nowadays widely used for analyzing multi-person consumption behavior. The model is particularly well-suited for addressing our research question, because it defines rational group consumption as a Pareto efficient allocation over group members. Importantly, this is the sole assumption that is made regarding the intra-group decision process. This reinforces the relevance of the

empirical findings, as it avoids bias through additional, more debatable assumptions or a specific game-theoretical set-up. In our particular context, a convenient implication of the Pareto efficiency assumption is that it allows us to define personalized prices to quantify consumption externalities in monetary terms. Specifically, these personalized prices reveal the willingness-to-pay of each group member for the own consumption, the other’s consumption and/or the equality of consumption.

Technically, to identify these personalized prices we will make use of a revealed preference methodology.¹ This methodology has a number of attractive features within the present context. Most notably, it is intrinsically nonparametric, which means that it does not require a prior parametric/functional specification of the individual preferences. This minimizes the risk that our empirical measurement of preference externalities (and the conclusions that are drawn from it) is confounded by some non-verifiable (and, thus, possibly erroneous) structure that is imposed on the consumption decision process. Next, from a practical point of view, the methodology evaluates rationality of group behavior through testable conditions that are easily verified on data sets with a limited number of consumption choices (like in our application). Attractively, this also means that the methodology does not need pooling of consumption data associated with different groups of consumers. The rationality of each group can be evaluated separately, which implies that we can maximally account for inter-group heterogeneity. Thus, our use of revealed preference methods avoids functional misspecification and debatable homogeneity assumptions, which effectively obtains a very “pure” empirical assessment.

Given our particular research interest, we define new “altruism” and “inequality aversion” parameters. Our altruism parameter captures the level of willingness-to-pay for the other’s consumption that is required to rationalize the observed consumption as Pareto efficient. Conveniently, the parameter is situated between zero and one and has a natural degree interpretation. The minimal value of zero means that we can rationalize behavior in terms of purely selfish consumers (i.e. consumers only care for the own consumption), while the maximal value of one indicates that rationalization is possible only for consumers who are allowed to care exclusively for the others’ consumption (and not for their own consumption). Next, our inequality aversion parameter captures the level of willingness-to-pay for equality of consumption that is required for rationalizability. Once more, the minimal value of zero indicates rationalizability in terms of purely selfish consumers, while the maximal value of one indicates that the group’s consumption allocation can only be rationalized through willingness-to-pay for equality.

Thus, lower parameter values generally suggest that behavior is more consistent with the standard model of selfish behavior, while higher values reflect a stronger prevalence of externalities in consumption. By varying the altruism parameter, we can define a whole continuum of models nested between the standard model of purely selfish behavior and the

¹See Cherchye et al. (2007, 2011) for revealed preference methodology to assess consumption decisions in terms of the cooperative consumption model. These authors build on early contributions of Samuelson (1938), Afriat (1967), Diewert (1973) and Varian (1982), who focused on rational (i.e. utility maximizing) individual behavior. Sippel (1997) argues that revealed preference methods are particularly useful in combination with experimental data such as the ones used in our own application. See also Harbaugh et al. (2001) and Bruyneel et al. (2012), who use revealed preference methods to assess the rationality of children’s individual consumption decisions.

general cooperative model (which allows for unrestricted levels of altruism) in the sense of Browning and Chiappori (1998). By varying the inequality aversion parameter, we extend the standard model of purely selfish behavior in an alternative direction, which also adds the possibility of negative consumption externalities to the structural model of cooperative group consumption (see Section 2 for details).

Children and externalities. We use our methodology to investigate the presence of externalities in children’s joint consumption behavior. Because observational data on joint consumption decisions made by children are typically not available, we designed a laboratory experiment that is specially tailored to obtain the data required for our revealed preference methodology. In particular, we first randomly assigned the children that participated to our experiment into dyads. Subsequently, we invited these dyads to jointly choose a series of consumption bundles composed of three commodities (grapes, mandarins and letter biscuits). Once these bundles had been selected, we also registered the associated intra-dyad allocations of the quantities, which gave us all the necessary information to identify our altruism and inequality aversion parameters for the consumption choices that were made. We believe that the minimalistic set-up of our experiment contributes to its external validity.² The fact that children are allowed to distribute the chosen quantities freely within the dyad implies that there is no clear trade-off between efficiency and equality in our study. This is a natural starting point, since a priori there is no reason for inequality averse children to consume inefficiently.

We have several motivations to select children as a population to illustrate our method. The first motivation is pragmatic. Children have an increasing economic impact, but a disproportionately large chunk of children’s economic influence comes through joint decisions, either with their parents (see, for example, Calvert (2008)) or their peers (see, for example, Wouters et al. (2010)). The growing understanding of children’s economic rationality (Harbaugh et al. (2002) and Seguin et al. (2007)) is therefore incomplete if we do not know how their decision making is modulated in joint decision making.

By focusing on joint consumption decisions, we extend the analyses of Andreoni and Miller (2002), Fisman et al. (2007) and Cox et al. (2008), who used a revealed preference methodology to investigate individual choices in a modified dictator game. These authors invited individual respondents to divide money between themselves and hypothetical counterparties. However, in many settings, children (i.e. siblings, friends, classmates) jointly decide on which activities to engage in, on how to allocate toys or candy, etc. Therefore, in our study we let the children face a real decision-maker, with whom they interact face-to-face to eventually reach consensus on the within-group consumption allocation. As such, a main feature of our analysis is that we do not treat children as dictatorial decision makers, which – in our opinion – substantially enhances the practical relevance of our findings.

Our second motivation is theoretical. Strategic concerns may distort the impact of prosocial motives (inequality aversion and altruism) on decisions. Recent research indeed showed

²In this respect, we remark that the type of data that we use in our application, with observed intra-group allocations, are also available in observational (household consumption) settings. This shows the usefulness of our methodology beyond the experimental context that we consider here. We will return to this last point in more detail in the concluding section.

that thinking about economic decisions in interdependent situations tends to reduce prosocial behavior (Cornelissen et al. (2011) and Cone and Rand (2014)). A child population is therefore particularly suited to study the interplay of these two motives, because their level of strategic thinking is limited (Kromm et al. (2015)) and, hence, their behavior can be considered as more pure. A child population also allows us to investigate the effect of age on the emergence and interplay of the two motives (Eisenberg et al. (2007) and Fehr et al. (2013)). We therefore decided to sample from three ages: kindergarten, third graders, and six graders.

As a final motivation, gaining a deeper insight into the prosocial characteristics of children can provide useful information for parents, caretakers and teachers. In a sense, it assesses the need to “paternalistically” guide children’s intra-group consumption allocations. As we discuss in detail further on, there is no clear consensus in the literature on how age, friendship and gender relate to prosocial behavior. The cognitive developments of children are often related to significant changes in prosocial behavior (see, for example, Fehr and Schmidt (1999) for an overview of the literature). As such, we can expect substantial heterogeneity in altruism and/or inequality aversion across children of different ages. Similarly, our set-up allows us to assess the impact of friendship and gender by considering joint consumption decisions of children with various degrees of friendship and/or gender composition.

As a related note, altruism is often modeled by using “caring” preferences in the Beckerian sense. Essentially, this means that others’ aggregate utility levels, and not others’ consumption quantities per individual good, enter as the direct arguments in individual utility functions.³ As argued by Chiappori (1992), under Pareto efficiency we have that purely selfish preferences are empirically indistinguishable from caring preferences: the two models have exactly the same testable implications for observed group consumption behavior. In turn, this implies that we cannot meaningfully check the empirical validity of the caring model (relative to the selfish model). Importantly, however, the caring model imposes a rather specific structure on the nature of altruism: it assumes that the marginal rate of substitution between individually consumed goods is independent of the goods consumed by the other. It may often be difficult to convincingly motivate this assumption. For example, it is very likely that children directly compare the quantities consumed per commodity rather than individuals’ aggregate utility levels. In the current study, we avoid this interpretational problem by focusing on a more general type of preferences characterized by consumption externalities.

Our experimental analysis leads us to conclude that the purely selfish model (and, hence, also the empirically equivalent caring model) does not provide a good description of the children’s observed consumption choices. Positive levels of altruism and inequality aversion considerably improve the goodness-of-fit of our models. It turns out that, for our sample of children, altruism has more impact than inequality aversion. Moreover, we observe substantial heterogeneity in the altruism parameter across children dyads. Therefore, in a following step, we relate the degree of altruism to observable child characteristics, and find that our altruism parameter is significantly correlated with age and friendship. As expected, dyads composed of two good friends also show a higher willingness-to-pay for each other’s consumption. Finally, we conclude that children of the sixth grade are generally less altruistic

³See Becker (1974, 1991).

than the younger children (of kindergarten and the third grade).

Outline. The remainder of this paper unfolds as follows. Section 2 sets out our revealed preference methodology to measure the degree of altruism and inequality aversion. Section 3 presents the results of our simulation analysis that studies the empirical performance of our newly proposed method. Section 4 contains our experimental design and the results of our empirical application. Section 5 concludes.

2 Group consumption with non-selfish individuals

To set the stage, we first present the cooperative model under the assumption of selfish group members. Then, we introduce a more general model, which departs from the assumption of selfishness in two different directions. The first extension encompasses different specifications of altruism, thereby nesting the purely selfish model and the general cooperative model in the spirit of Browning and Chiappori (1998). The second modification adds preferences for equality, and extends the cooperative model with negative consumption externalities that stem from inequality aversion. We show that the willingness-to-pay for the others' consumption and the willingness-to-pay for equal consumption is captured by personalized prices. This will enable us to subsequently define intuitive *altruism* and *inequality aversion* parameters.

Before we can present our model, we first need to specify the type of data that we have in mind when applying our methodology. Our application in Section 4 contains information on dyads' consumption behavior.⁴ We have a separate consumption data set for every single dyad, which contains the observed consumption choices for a series of decision situations. Formally, this set takes the form $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$ and consists of price vectors $\mathbf{p}_t \in \mathbb{R}_{++}^n$ and quantity vectors $\mathbf{q}_t^m \in \mathbb{R}_+^n$ for every observed decision situation t . Each vector \mathbf{q}_t^m represents the quantities of all goods allocated to individual m ($m = 1, 2$).

2.1 Selfish individuals

The specific feature of selfish consumer behavior is that individual utilities are independent of others' consumption. Formally, in our dyad setting each member m has a utility function $U^m(\mathbf{q}^m)$ that only varies with the own consumption \mathbf{q}^m . Throughout, we will assume that utility functions are well-behaved.⁵ Then, we get the following definition of rational cooperative (i.e. Pareto efficient) consumption behavior under selfishness.

Definition 1 Consider a data set $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$. A pair of utility functions U^1 and U^2 provides a *cooperative rationalization under selfishness* of S if and only if, for each observation $t = 1, \dots, T$, there exist Pareto weights $\mu_t^1, \mu_t^2 \in \mathbb{R}_{++}$ such that $\mu_t^1 U^1(\mathbf{q}_t^1) +$

⁴We note that it is fairly easy to extend our following methodology towards settings with more than two group members.

⁵We say that a utility function is well-behaved if it is nonsatiated, continuous, nondecreasing and concave in its arguments.

$\mu_t^2 U^2(\mathbf{q}_t^2)$ equals

$$\begin{aligned} & \max_{\mathbf{z}^1, \mathbf{z}^2 \in \mathbb{R}_+^n} \mu_t^1 U^1(\mathbf{z}^1) + \mu_t^2 U^2(\mathbf{z}^2) \\ & \quad s.t. \\ & \quad \mathbf{p}'_t(\mathbf{z}^1 + \mathbf{z}^2) \leq \mathbf{p}'_t(\mathbf{q}_t^1 + \mathbf{q}_t^2). \end{aligned}$$

Thus, Pareto efficiency requires that the dyad's consumption behavior can be represented as if it maximizes a weighted sum of the individual utility functions, subject to the dyad's budget constraint (with the dyad's budget equal to $\mathbf{p}'_t(\mathbf{q}_t^1 + \mathbf{q}_t^2)$). We remark that the individual Pareto weights $\mu_t^1, \mu_t^2 \in \mathbb{R}_{++}$ are allowed to vary across the observations t . The implication is that the "bargaining power" of a particular individual need not be constant but may depend on the specific decision situation at hand (defined by prices \mathbf{p}_t and budget $\mathbf{p}'_t(\mathbf{q}_t^1 + \mathbf{q}_t^2)$).

Our revealed preference characterization of rational cooperative behavior uses the concept GARP (Generalized Axiom of Revealed Preference), which is defined as follows.

Definition 2 (GARP) The set $S^m = \{(\mathbf{p}_t; \mathbf{q}_t^m); t = 1, \dots, T\}$ is consistent with GARP if there exists a binary revealed preference relation R such that

1. if $\mathbf{p}'_t \mathbf{q}_t^m \geq \mathbf{p}'_t \mathbf{q}_v^m$, then $\mathbf{q}_t^m R \mathbf{q}_v^m$;
2. if $\mathbf{q}_t^m R \mathbf{q}_r^m, \mathbf{q}_r^m R \mathbf{q}_s^m, \dots, \mathbf{q}_u^m R \mathbf{q}_v^m$, then $\mathbf{q}_t^m R \mathbf{q}_v^m$;
3. if $\mathbf{q}_t^m R \mathbf{q}_v^m$, then $\mathbf{p}'_v \mathbf{q}_t^m \geq \mathbf{p}'_v \mathbf{q}_v^m$.

As shown by Varian (1982), consistency with GARP guarantees the existence of an individual utility function U^m that is consistent with the individual m 's choices captured by the subset $S^m = \{(\mathbf{p}_t; \mathbf{q}_t^m); t = 1, \dots, T\}$. That is, every observed choice \mathbf{q}_t^m maximizes this utility function U^m subject to the budget constraint defined by the prices \mathbf{p}_t and the budget $\mathbf{p}_t \mathbf{q}_t^m$.

We can then present the revealed preference characterization of rational cooperative behavior with selfish dyad members (see Cherchye et al. (2011) for a formal proof).

Proposition 1 Let $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$ be a set of observations. The following statements are equivalent:

1. There exists a pair of utility functions U^1 and U^2 that provide a *cooperative rationalization under selfishness* of S .
2. The subsets $S^1 = \{(\mathbf{p}_t; \mathbf{q}_t^1); t = 1, \dots, T\}$ and $S^2 = \{(\mathbf{p}_t; \mathbf{q}_t^2); t = 1, \dots, T\}$ are both consistent with GARP.

Varian (1982) presented a combinatorial test of GARP. More recently, Cherchye et al. (2011) have shown that the GARP conditions in Proposition 1 can also be verified by solving a linear programming problem with binary integer variables. A similar programming problem can also be used to verify the revealed preference conditions in our following Proposition 2 as we discuss in Appendix A.2.

2.2 Non-selfish individuals

Other-regarding preferences. The utility function of non-selfish consumers is no longer exclusively defined over their own private consumption. In what follows, we investigate two well-known sources of other-regarding preferences: altruism and inequality aversion. Altruism implies that consumers care directly for the consumption of others. Formally, this adds \mathbf{q}^2 and \mathbf{q}^1 to the utility functions of individuals 1 and 2, respectively. Inequality averse consumers also care about equality of consumption. This adds the vector \mathbf{d} to the utility functions, with \mathbf{d} composed of elements $d_j = -|q_j^1 - q_j^2|$ ($j = 1, \dots, n$). In words, each entry d_j equals the negative of the absolute intra-dyad difference between the own and the other's consumption. By construction, we have that $d_j \leq 0$. For every good j , the value of d_j quantifies the degree of equality of consumption, with lower values revealing more inequality.⁶

Our general model defines well-behaved utility functions that depend on own consumption, the other's consumption and equality of consumption:

$$U^1(\mathbf{q}^1, \mathbf{q}^2, \mathbf{d}) \text{ and } U^2(\mathbf{q}^1, \mathbf{q}^2, \mathbf{d}).$$

Given our particular research question, we use a definition of rational cooperative behavior that allows for different degrees of altruism and inequality aversion. Specifically, we capture the degree of altruism by the parameters π and ε , and the degree of inequality aversion by the parameters δ and $\gamma_{t,j}^m$.⁷ We will explain the meaning of these parameters in more detail below. Furthermore, we will discuss the specific monetary interpretations of π and δ in the polar cases of purely altruistic and purely inequality averse behavior.

Definition 3 Consider a data set $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$ and let $d_{t,j} = -|q_{t,j}^1 - q_{t,j}^2|$. Define $x_{t,j}^m = 1$ if $q_{t,j}^m < q_{t,j}^l$ and $x_{t,j}^m = -1$ if $q_{t,j}^m \geq q_{t,j}^l$ (for $j = 1, \dots, n; t = 1, \dots, T; m, l = 1, 2; m \neq l$.) Assume $\pi, \delta \in [0, 1]$.

A pair of utility functions U^1 and U^2 provides a *cooperative rationalization under π -altruism and δ -inequality aversion* of S if and only if, for each observation $t = 1, \dots, T$, there exist Pareto weights $\mu_t^1, \mu_t^2 \in \mathbb{R}_{++}$ such that $\mu_t^1 U^1(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) + \mu_t^2 U^2(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t)$ equals

$$\max_{\mathbf{z}^1, \mathbf{z}^2 \in \mathbb{R}_+^n} \mu_t^1 U^1(\mathbf{z}^1, \mathbf{z}^2, \mathbf{d}) + \mu_t^2 U^2(\mathbf{z}^1, \mathbf{z}^2, \mathbf{d})$$

s.t.

$$\mathbf{p}'_t(\mathbf{z}^1 + \mathbf{z}^2) \leq \mathbf{p}'_t(\mathbf{q}_t^1 + \mathbf{q}_t^2);$$

$$d_j = -|z_j^1 - z_j^2| \quad \text{with } j = 1, \dots, n;$$

⁶By defining the level of inequality d_j in each commodity, the model can attach different levels of inequality aversion to different goods. Furthermore, the general formulation $U(\mathbf{q}^1, \mathbf{q}^2, \mathbf{d})$ encompasses a large variety of utility specifications, ranging from $V(\mathbf{q}^1, \mathbf{q}^2, \sum_j d_j)$ to $V'(\mathbf{q}^1, \mathbf{q}^2, \min_j d_j)$ (with V and V' well-behaved utility functions).

⁷We consider two possible scenarios. First, $q_{t,j}^m < q_{t,j}^l$ implies $\gamma_{t,j}^m = \frac{\delta}{1 - \delta}$. Second, $q_{t,j}^m \geq q_{t,j}^l$ implies $\gamma_{t,j}^l = \frac{\delta}{1 + \delta}$; see also below for more discussion. For this reason, $\gamma_{t,j}^m$ generally depends on the individual m , observation t and commodity j under consideration.

$$\varepsilon = \frac{\pi}{1 - \pi}; \gamma_{t,j}^m = \frac{\delta}{1 - \delta x_{t,j}^m}.$$

and for $j = 1, \dots, n$ and $m, l = 1, 2$ with $m \neq l$:

$$\mu_t^l \frac{\partial U^l}{\partial q_{t,j}^m} \leq \varepsilon \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right); \quad (1)$$

$$\mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}} \leq \gamma_{t,j}^m \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right). \quad (2)$$

Conditions (1)–(2) define upper bounds on the degree of other-regarding preferences by relating the consumption externalities to each member m 's marginal willingness-to-pay for his/her own consumption: $\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m}$. For $\varepsilon = \gamma_{t,j}^m = 0$ we get exactly the same rationalization condition as in Definition 1, which implies purely selfish dyad members.

First, the parameter ε relates the marginal willingness-to-pay of member l for the consumption of the other member m ($l \neq m$) to m 's marginal willingness-to-pay for his/her own consumption.⁸ In this sense, ε can be interpreted as an *altruism* parameter. It defines an upper bound on the marginal rate of substitution for every good j between the utility of the other person and own utility. Intuitively, if altruism is very important, the marginal willingness-to-pay for the other's consumption will be large, which implies that the data can be rationalized only for a high value of ε . Generally, by varying the value of ε we obtain rationalization conditions for different degrees of altruism.

Second, the parameters $\gamma_{t,j}^m$ relate the marginal willingness-to-pay for equality of consumption to m 's marginal willingness-to-pay for his/her own consumption. Therefore, the parameters can be interpreted as *inequality aversion* parameters. If inequality aversion is important, the marginal willingness-to-pay for equality will be large, which implies that the data can be rationalized only for high levels of $\gamma_{t,j}^m$.

Fixing the value of ε (or, similarly, $\gamma_{t,j}^m$) restricts consumption externalities by constraining the product of the individuals' Pareto weights and marginal utilities. Actually, the fact that we need to constrain both bargaining weights and marginal utilities has an intuitive interpretation. For example, an altruistic dyad member l cannot contribute to the consumption of the other member m if l has no bargaining power. More generally, the marginal willingness-to-pay for others' consumption will depend both on the individuals' marginal utilities for others' consumption and the individuals' Pareto weights. The same holds for inequality aversion.

Conveniently, by using parameters π and δ we can also derive revealed preference conditions for cooperative rational behavior that are linear in unknowns, which makes them easy to verify in practice. Moreover, this formulation allows us to replace the set of parameters $\gamma_{t,j}^m$ by a uniform inequality aversion parameter δ .

Revealed preference conditions. To define our revealed preference characterization of non-selfish behavior, we need some additional notation. Specifically, we define the personal-

⁸Definition 3 uses uniform parameters π and δ . In this respect, we remark that the commodities used in our experiment are all food items of similar nature, which –in our opinion– justifies this choice. Moreover, the parameters essentially bound marginal willingness-to-pay, rather than imposing equality across commodities. Finally, our theory and methodology can easily be generalized to deal with commodity-specific parameters π_j and δ_j .

ized prices

$$\begin{aligned}\mathbf{p}_t^{1,1} &= \frac{\mu_t^1}{\lambda_t} \frac{\partial U^1}{\partial \mathbf{z}_t^1}, \mathbf{p}_t^{2,2} = \frac{\mu_t^2}{\lambda_t} \frac{\partial U^2}{\partial \mathbf{z}_t^2}, \\ \mathbf{p}_t^{1,2} &= \frac{\mu_t^1}{\lambda_t} \frac{\partial U^1}{\partial \mathbf{z}_t^2}, \mathbf{p}_t^{2,1} = \frac{\mu_t^2}{\lambda_t} \frac{\partial U^2}{\partial \mathbf{z}_t^1}, \\ \mathbf{p}_t^{1,d} &= \frac{\mu_t^1}{\lambda_t} \frac{\partial U^1}{\partial \mathbf{d}_t}, \mathbf{p}_t^{2,d} = \frac{\mu_t^2}{\lambda_t} \frac{\partial U^2}{\partial \mathbf{d}_t},\end{aligned}$$

where λ_t is the Lagrange multiplier associated with the dyad's optimization problem in decision situation t (i.e. the marginal value of income). Intuitively, these personalized prices denote the marginal willingness-to-pay for the own consumption, the other's consumption and consumption equality (measured by \mathbf{d}_t), respectively. Using these concepts, we can state the next result, which generalizes Proposition 1 (Appendix A.1 contains the proof).

Proposition 2 Let $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$ be a set of observations and let $d_{t,j} = -|q_{t,j}^1 - q_{t,j}^2|$. Define $x_{t,j}^m = 1$ if $q_{t,j}^m < q_{t,j}^l$ and $x_{t,j}^m = -1$ if $q_{t,j}^m \geq q_{t,j}^l$ (for $j = 1, \dots, n; t = 1, \dots, T; m, l = 1, 2; m \neq l$.) The following statements are equivalent:

1. There exists a pair of utility functions U^1 and U^2 that provide a *cooperative rationalization under π -altruism and δ -inequality aversion* of S .
2. For all $t = 1, \dots, T$, there exist non-negative price vectors $\mathbf{p}_t^{1,1}, \mathbf{p}_t^{1,2}, \mathbf{p}_t^{2,1}, \mathbf{p}_t^{2,2}, \mathbf{p}_t^{1,d}$ and $\mathbf{p}_t^{2,d}$ such that

$$(a) \text{ the subsets } S^1 = \{(\mathbf{p}_t^{1,1}, \mathbf{p}_t^{1,2}, \mathbf{p}_t^{1,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\} \text{ and } S^2 = \{(\mathbf{p}_t^{2,1}, \mathbf{p}_t^{2,2}, \mathbf{p}_t^{2,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\} \text{ both satisfy GARP;}$$

(b) for all $j = 1, \dots, n$ and $m, l = 1, 2$ with $m \neq l$:

$$p_{t,j}^{m,m} + p_{t,j}^{l,m} + x_{t,j}^m (p_{t,j}^{1,d} + p_{t,j}^{2,d}) = p_{t,j};$$

(c) for all $j = 1, \dots, n$ and $m = 1, 2$:

$$(p_{t,j}^{1,d} + p_{t,j}^{2,d}) \leq \delta \left(p_{t,j}^{m,m} + x_{t,j}^m (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \right);$$

(d) for all $m, l = 1, 2$ with $m \neq l$:

$$\mathbf{p}_t^{l,m} \leq \pi(\mathbf{p}_t^{m,m} + \mathbf{p}_t^{l,m}).$$

Condition (a) imposes consistency with GARP on the individual subsets S^1 and S^2 . Different from Proposition 1, these conditions are now expressed in terms of the personalized prices $\mathbf{p}_t^{m,m}$, $\mathbf{p}_t^{m,l}$ and $\mathbf{p}_t^{m,d}$ (with $m, l = 1, 2$ and $m \neq l$).⁹

⁹The definition of GARP for this setting is readily analogous to Definition 2. For compactness we do not include a formal statement.

Next, Condition (b) relates the personalized prices to the observed prices \mathbf{p}_t via first-order restrictions. These restrictions have in common that the personalized prices associated with the own consumption, the other's consumption and consumption equality add up to the market price. This condition follows from our assumption that dyads act cooperatively. Actually, the adding up condition also implies that personalized prices can be interpreted as Lindahl prices associated with the Pareto efficient provision of public goods. This corresponds to the fact that private goods with externalities effectively get a public good character. For inequality aversion, we distinguish between $q_{t,j}^m < q_{t,j}^l$ (i.e. $x_{t,j}^m = 1$ as $q_{t,j}^m$ increases equality) and $q_{t,j}^m \geq q_{t,j}^l$ (i.e. $x_{t,j}^m = -1$ as $q_{t,j}^m$ decreases equality). If $q_{t,j}^m \geq q_{t,j}^l$ then member m not only pays the price $(p_{t,j} - p_{t,j}^{l,m})$ for an additional unit of $q_{t,j}^m$ but, because of inequality aversion, must also compensate both dyad members for the increased consumption inequality, which implies $p_{t,j}^{m,m} = (p_{t,j} - p_{t,j}^{l,m}) + p_{t,j}^{1,d} + p_{t,j}^{2,d}$. Conversely, the other member l receives a monetary subsidy $p_{t,j}^{1,d} + p_{t,j}^{2,d}$ for each unit of $q_{t,j}^l$, because increasing $q_{t,j}^l$ also increases equality. Analogously, if $q_{t,j}^m < q_{t,j}^l$, any additional unit of $q_{t,j}^m$ increases equality and, therefore, member m receives the monetary subsidy $p_{t,j}^{1,d} + p_{t,j}^{2,d}$.

The Conditions (c) and (d) introduce the inequality aversion and altruism parameters (δ and π). The inequality aversion parameter δ controls the ratio of willingness-to-pay for own consumption and willingness-to-pay for equality. Larger values of δ enable stronger preferences for equality. Notice that Condition (c) boils down to $(p_{t,j}^{1,d} + p_{t,j}^{2,d}) \leq \delta(p_{t,j} - p_{t,j}^{l,m})$ when combined with the first-order restrictions from (b). In other words, the contribution of inequality aversion $p_{t,j}^{1,d} + p_{t,j}^{2,d}$ to the market price $p_{t,j}$ is always constrained by the parameter δ . Finally, π measures the ratio of each member m 's willingness-to-pay for own consumption and his/her willingness-to-pay for the other's consumption.

In the final part of this section, we will show that the parameters π and δ have straightforward monetary interpretations, in terms of the contributions from altruism and inequality aversion to the total willingness-to-pay. We will do so by considering two special cases of the model in Definition 3, i.e. purely altruistic and purely inequality averse behavior.

2.3 Benchmark cases

Cooperative rationalization under π -altruism and δ -inequality aversion (as stated in Definition 3) allows for a better *fit* of behavior that stems from consumption externalities. However, empirical analysts may also seek to recover specific types of externalities and thereby focus on *either* altruism (π) *or* inequality aversion (δ). Indeed, given its generality, the model in Definition 3 may lack the discriminatory power to accurately *identify* a specific source of other-regarding preferences. Furthermore, our following Corollary 1 will show that the parameters π and δ have a straightforward monetary interpretation in two polar cases of the general model.

In the remainder of this paper, we will mainly focus on the special cases of *pure altruism* and *pure inequality aversion*. In the concluding section, we will briefly elaborate on the usefulness of the more general model with both altruism and inequality aversion. Most notably, it allows for modeling altruism in one commodity and inequality aversion in another. For example, this can be relevant in a labor supply setting, as the consumption of commodities and the consumption of leisure may well be expected to produce different types of externalities.

Starting from Definition 3, a cooperative rationalization under π -altruism corresponds to $\delta = 0$ and, similarly, a cooperative rationalization under δ -inequality aversion to $\pi = 0$. The associated characterizations of (pure) altruism and inequality aversion follow directly from Proposition 2. Conveniently, these testable conditions are linear in the unknowns (π , δ and personalized prices), which was not the case before (see Conditions (c) and (d) in Proposition 2).¹⁰

Corollary 1 Let $S = \{(\mathbf{p}_t; \mathbf{q}_t^1, \mathbf{q}_t^2); t = 1, \dots, T\}$ be a set of observations and let $d_{t,j} = -|q_{t,j}^1 - q_{t,j}^2|$.

1. There exists a pair of utility functions U^1 and U^2 that provide a *cooperative rationalization under π -altruism* of S if and only if the conditions (a) – (d) in Proposition 2 hold with $\mathbf{p}_t^{1,d} = \mathbf{p}_t^{2,d} = 0$. Moreover, π provides an upper bound on the monetary contribution to $p_{t,j}$ that stems from altruism:

$$\begin{aligned} \frac{p_{t,j}^{2,1}}{p_{t,j}} &\leq \pi; \\ \frac{p_{t,j}^{1,2}}{p_{t,j}} &\leq \pi. \end{aligned}$$

2. There exists a pair of utility functions U^1 and U^2 that provide a *cooperative rationalization under δ -inequality aversion* of S if and only if the conditions (a) – (d) in Proposition 2 hold with $\mathbf{p}_t^{1,2} = \mathbf{p}_t^{2,1} = 0$. Moreover, δ provides an upper bound on the monetary contribution to $p_{t,j}$ that stems from inequality aversion:

$$\frac{\left(p_{t,j}^{1,d} + p_{t,j}^{2,d}\right)}{p_{t,j}} \leq \delta.$$

First, the altruism parameter π in statement 1 of Corollary 1 indicates that each dyad member l “pays” (at most) a fraction π of member m ’s consumption of any good j . More precisely, it puts an upper bound on the monetary contribution of each member for his/her partner’s consumption. If $\pi = 0$, each member fully pays for her own private consumption, i.e. there are no externalities and behavior can be rationalized as purely selfish. We then get exactly the conditions for a rationalization under selfishness that we stated in Proposition 1. Higher values of π enable stronger altruism. In the extreme case with $\pi = 1$, we allow for the possibility that m ’s consumption is fully financed by the other member l , which means that member m does not contribute to his/her own consumption at all.

Second, the inequality aversion parameter δ in statement 2 of Corollary 1 indicates that (at most) a fraction δ of each member’s consumption is financed for reasons of equalizing consumption. When $\delta = 0$, we get exactly the conditions for a rationalization under selfishness that we stated in Proposition 1. In the extreme case with $\delta = 1$, we allow for the possibility

¹⁰Notice that a cooperative rationalization under π -altruism is equivalent to a cooperative rationalization under π -altruism and 0-inequality aversion. Similarly, a cooperative rationalization under δ -inequality aversion is equivalent to a cooperative rationalization under 0-altruism and δ -inequality.

that one member’s consumption is fully financed by both members’ willingness-to-pay for equal consumption.¹¹

To conclude, we highlight that the formal distinction between altruism and inequality aversion is non-trivial. A particular data set may satisfy the conditions for rationalization under π -altruism in statement 1 of Corollary 1, but not the conditions for rationalization under δ -inequality aversion in statement 2 of Corollary 1, and vice versa. In other words, the altruism and inequality aversion models are not nested with each other. We show this point through numerical examples in Appendix B.

3 Numerical and simulation analysis

In our simulation analysis, we assume a given parametric specification of the individual preferences and the bargaining process. That is, we generate data that are fully consistent with respectively the egoism, altruism and inequality aversion models for some specific bargaining process. Then, we apply our revealed preference conditions (in Corollary 1) to the generated data, and we evaluate how well we can recover (lower) bounds on the true levels of altruism and inequality aversion. Subsequently, we will also analyze the impact of measurement errors (in consumption quantities) and increased sample size on our recovery results.

Set-up. We start by considering the same price-income regimes as in our experiment in Section 4 (i.e. 9 different price configurations and a fixed budget of 24; see also Table 10). Our following analysis will show that our method can be powerful even for such a small data set. As such, it also motivates our experimental design in Section 4, as it demonstrates that this design effectively does allow us to meaningfully analyze altruism and inequality aversion in the observed consumption behavior.

We consider a setting with 3 commodities. The individuals’ preferences are represented by a Constant-Elasticity-of-Substitution (CES) utility function, with $\frac{1}{1-\rho}$ the elasticity of substitution.¹²

$$U^1(\mathbf{q}^1, \mathbf{q}^2, \mathbf{d}) = \left[\sum_{j=1}^3 \alpha_j^1 (q_j^1)^\rho + \alpha_j^2 (q_j^2)^\rho + \alpha_j^d (d_j)^\rho \right]^{\frac{1}{\rho}} \quad (3)$$

$$U^2(\mathbf{q}^1, \mathbf{q}^2, \mathbf{d}) = \left[\sum_{j=1}^3 \beta_j^1 (q_j^1)^\rho + \beta_j^2 (q_j^2)^\rho + \beta_j^d (d_j)^\rho \right]^{\frac{1}{\rho}} \quad (4)$$

¹¹The shadow prices associated with unequally distributed commodities are always bounded from above by the market price (condition (b) in Proposition 2). For these commodities, the generalization $\delta > 1$ does not increase the range of feasible shadow prices and, therefore, is not useful. More generally, the requirement $\delta \leq 1$ allows us to compare monetary deviations from selfishness because of altruism and deviations from selfishness because of inequality aversion.

¹²We use $\rho = 0.85$ in order to have sufficient sensitivity of demand to changing prices. Furthermore, without losing generality, we reformulate $d_j = 24 - |q_j^1 - q_j^2|$ to avoid non-negative entries in the CES utility function.

In the main part of this section, individual 1 will have egoistic preferences that comply with $\alpha_1^1 = 1 - 2\theta$ and $\alpha_3^1 = 2\theta$. This implies positive weights for individual 1's consumption of goods 1 and 3. For $\theta > 0.25$, individual 1 has stronger preferences for good 3. We remark that the purely selfish nature of individual 1's preferences is not crucial for our following arguments to hold. However, it considerably facilitates our discussion as it allows us to better structure our reasoning.

Next, we consider two specifications for individual 2's preferences:

$$\beta_1^1 = \theta, \beta_1^2 = 0.9(1 - \theta) \text{ and } \beta_2^2 = 0.1(1 - \theta) \quad (5)$$

$$\beta_1^d = \theta, \beta_1^2 = 0.9(1 - \theta) \text{ and } \beta_2^2 = 0.1(1 - \theta) \quad (6)$$

While these two specifications may seem to be quite alike, they have rather different interpretations: parameters (5) imply that individual 2 altruistically cares for the consumption of good 1 by individual 1, while parameters (6) imply that individual 2 is inequality averse with respect to the first commodity. In both cases, θ determines the level of altruism/inequality aversion. Higher levels of θ correspond to more outspoken other-regarding preferences, which entail larger deviations from the purely selfish model and, hence, a higher probability to recover strictly positive values for π and δ . Next, both specifications have in common that individual 2 strongly prefers good 1 and weakly prefers good 2 for own consumption.

Finally, as is typically done in the literature on cooperative consumption models, we assume that the individuals' relative bargaining weights depend on the good prices, by using $\mu^1 = 1$ and

$$\mu^2(p_1, p_2, p_3) = \left(\frac{p_1}{2.5(p_2 + p_3) - 0.999} \right)^3. \quad (7)$$

Thus, the bargaining weight of individual 2 is always increasing in the price of good 1: by increasing p_1 the bargaining power shifts in favor of individual 2 and, hence, more of good 1 will be purchased. Also note that the bargaining weight is independent of θ , which means that the bargaining process remains constant if we vary θ . As an implication, we can effectively interpret the different empirical results for different θ in terms of preference differences (for fixed bargaining positions).

Recovery of altruism and inequality aversion parameters. As a first exercise, we verify whether data characterized by strictly positive levels of altruism or inequality aversion also yield strictly positive estimates for the parameters π or δ (when applying our revealed preference conditions). In particular, using the preferences specified above, we compute for different values of θ the chosen consumption bundles in the 9 price regimes. Subsequently, for these simulated data sets we compute the lowest values of π and δ that obtain consistency with the revealed preference conditions in Corollary 1. To recall, values of π and δ equal to

Altruism		Inequality aversion	
θ	π	θ	δ
0.39	0	0.39	0.033
0.40	0	0.392	0.082
0.41	0.149	0.394	0.131
0.42	0.337	0.396	0.182
0.43	0.512	0.398	0.234
0.44	0.611	0.4	0.288
0.45	0.679	0.402	0.344
0.46	0.729	0.404	0.413
0.47	0.766	0.406	0.496
0.48	0.795	0.408	0.559
0.49	0.817	0.41	0.586

Table 1: Lower bounds on altruism π and inequality aversion δ for different values of θ . Individual preferences are specified in (3) and (4) and the decision process in (7). In the columns Altruism and Inequality aversion we use, respectively, (5) and (6) to specify the preference parameters of individual 2.

zero imply that we can rationalize the (simulated) behavior in terms of purely selfish preferences, whereas higher values correspond to a greater degree of externalities (i.e. altruism and inequality aversion, respectively).

We first consider the case where individual 2 is altruistic (i.e. preferences correspond to specification (5)). We let θ increase from 0.39 to 0.49 and verify the effect on our estimates of π . Given our set-up, the true level of altruism, say π^* , is close to one, since it is a product of the preferences and the bargaining weight. So, the question is whether our estimates π will also approach unity. The second column of Table 1 contains our results. Clearly, π is increasing in θ , and our estimates get closer to one when the marginal rate of substitution $\frac{\partial U^2}{\partial q_1^1} / \frac{\partial U^1}{\partial q_1^1}$ (and, hence, the parameter θ) becomes large.

Next, let us suppose that individual 2 is inequality averse (i.e. preferences correspond to specification (6)). For this case, we let θ increase from 0.39 to 0.41.¹³ As before, the true level of inequality aversion, say δ^* , is close to one. The final column of Table 1 contains the estimates obtained on the basis of our revealed preference conditions. Once more, the bounds are improving if θ increases, albeit that this improvement is somewhat less pronounced than in the altruistic case.

Summarizing, these first simulation results show that our methodology can effectively detect altruism and inequality aversion, even when using a data set with only 9 observations. As expected, our revealed preference estimates of π and δ are rising monotonically with the individuals' altruism and inequality aversion, and they come closer to the true π^* and δ^* when other-regarding preferences are more pronounced.

¹³We choose the upper bound 0.41 because the specification (6) is no longer consistent with the requirement that $\delta \leq 1$ for θ above 0.41.

Altruism					Inequality aversion				
	No error	$\Delta = 50$	$\Delta = 10$	$\Delta = 2.5$		No error	$\Delta = 50$	$\Delta = 10$	$\Delta = 2.5$
θ					θ				
0.39	0	0	0	0	0.39	0.033	0.033	0.033	0.035
0.40	0	0	0	0.015	0.392	0.082	0.081	0.081	0.082
0.41	0.149	0.149	0.149	0.148	0.394	0.131	0.131	0.133	0.141
0.42	0.337	0.337	0.341	0.347	0.396	0.182	0.183	0.183	0.180
0.43	0.512	0.512	0.514	0.516	0.398	0.234	0.234	0.235	0.244
0.44	0.611	0.611	0.610	0.613	0.40	0.288	0.289	0.286	0.303
0.45	0.679	0.679	0.678	0.675	0.402	0.344	0.344	0.342	0.343
0.46	0.729	0.729	0.728	0.731	0.404	0.413	0.412	0.412	0.420
0.47	0.766	0.766	0.765	0.764	0.406	0.496	0.496	0.494	0.465 (8)
0.48	0.795	0.795	0.794	0.796	0.408	0.559	0.559	0.558	0.510 (24)
0.49	0.817	0.817	0.817	0.815	0.41	0.586	0.586 (18)	0.580 (42)	0.543 (48)
mean dev.	0	0	0.1%	0.4%	mean dev.	0	0	0.2%	1.5%

Table 2: Impact of measurement error ($\omega_{t,j} = \frac{\sigma_{t,j} - \frac{1}{2}}{\Delta}$); average lower bounds on altruism π and inequality aversion δ (between brackets: number of inconsistent data sets) for different values of θ . Individual preferences are specified in (3) and (4) and the decision process in (7). In the columns Altruism and Inequality aversion we use, respectively, (5) and (6) to specify the preference parameters of individual 2.

Measurement error. As a following exercise, we assess the impact of errors in the chosen quantities on the estimates of π and δ , for the same setting as in the first exercise. Specifically, for each choice situation and each separate good, we add random variation (noise) to the consumption bundles \mathbf{q}_t , which are generated according to the preferences and bargaining process specified above. This obtains the new quantities \mathbf{q}'_t , with entries

$$q'_{t,j} = (1 + \omega_{t,j})q_{t,j}$$

and $\omega_{t,j} = \frac{\sigma_{t,j} - \frac{1}{2}}{\Delta}$. In our simulations, the value $\sigma_{t,j}$ is drawn at random from a uniform distribution on the unit interval, and Δ is a scale parameter ranging from 50 (yielding maximal relative quantity errors of 1 percent) to 2.5 (yielding maximal relative quantity errors of 20 percent). The original quantities $q_{t,j}$ are modified by a factor $\omega_{t,j}$ and, subsequently, the resulting vector \mathbf{q}'_t is rescaled so that total outlays equal the original budget level (i.e. 24).¹⁴

Our results are reported in Table 2. Each row contains the average estimates of altruism and inequality aversion based on 100 different simulated data sets of 9 observations. The final row reports the relative difference (on average) between our new estimates of π and δ and the original estimates with $\omega_{t,j} = 0$.

Not very surprisingly, we find that lower values for Δ (and hence higher values for $\omega_{t,j}$) generally give rise to larger absolute deviations from the altruism and inequality aversion estimates without error. However, it is also fair to say that the differences are rather small.

¹⁴This rescaling guarantees that our results are not affected by extra income variation on top of measurement error.

The altruism estimates deviate by an average of 0.4 percent at most, while the average difference for the inequality aversion estimates amounts to 1.5 percent at most. Next, the measurement errors do not necessarily imply an obvious bias in the parameter estimates; there is no clear monotone relationship between the magnitude of the error and the estimated levels of π and δ .

As a final remark, we indicate that introducing noise can make the simulated data inconsistent with the revealed preference conditions. For our simulation exercise, this turned out to be the case for the inequality aversion model when Δ becomes small (and $\omega_{t,j}$ large). We have reported the numbers of these data sets between brackets. For example, for $\Delta = 2.5$ and $\theta = 0.41$ we find that 48 percent of the simulated datasets for our inequality aversion model violates the associated rationalization conditions.

Increased sample size. So far, we have considered a setting with only 9 different price regimes (and correspondingly chosen quantity bundles), which are characterized by limited price variation. In empirical applications, one may often exploit more price variation in the observed demand behavior. For example, if consumption demand functions are available, one may consider a continuum of possible prices. To study the impact of increased price variation, we conduct an extra analysis that makes use of additional consumption/price observations.

More specifically, we consider exactly the same set-up as above (without measurement error), but now we add information on price regimes that are specially tailored to exploit the preference specification that we use in our simulation. In particular, we fix the price of good 1 at 9, while the prices of goods 2 and 3 are set equal to $3 + P$ and $1 - P$, for P varying between 0 and 0.9.¹⁵ Obviously, different values of P will give rise to different bundles of goods depending on the specification of the individual preferences. We remark that the bargaining weights μ^1 and μ^2 are unaffected by P .

For this new data set, let $\bar{\pi}$ and $\bar{\delta}$ represent the recovered values of our altruism and inequality aversion parameters. The results of this analysis are presented in Table 3. For the sake of comparison, we repeat the estimates of our first exercise, π and δ . Interestingly, the new estimates $\bar{\pi}$ and $\bar{\delta}$ are considerably higher than our original estimates π and δ . The gains are present at almost any level of θ . Moreover, our new estimates are very close to the true levels of altruism and inequality aversion (π^* and δ^* , which approximate unity for our set-up, as explained above). Once more, the estimates generally increase if the preferences for altruism or inequality aversion are more outspoken (i.e. θ increases).

As a concluding note, by using the data of our last exercise, we can further illustrate the independence of the altruism and inequality aversion models. In this respect, we recall that Appendix B provides numerical examples showing that these two models have distinct testable implications. Here, we can show that this independence is not only a theoretical curiosity but may also be detected in real data.

In particular, one can verify that our new data generated for the altruistic preference specification (5) and $\theta \geq 0.48$ cannot be rationalized in terms of the inequality aversion model, i.e. there does not exist a value of δ that makes these data meet the rationalization conditions in Corollary 1. By contrast, these data can be rationalized in terms of the altruism

¹⁵Specifically, we used $P = 0.1, 0.2, \dots, 0.9$.

Altruism			Inequality aversion		
θ	π	$\bar{\pi}$	θ	δ	$\bar{\delta}$
0.39	0	0.817	0.39	0.033	0.926
0.40	0	0.885	0.392	0.082	0.940
0.41	0.149	0.915	0.394	0.131	0.950
0.42	0.337	0.934	0.396	0.182	0.956
0.43	0.512	0.951	0.398	0.234	0.961
0.44	0.611	0.961	0.4	0.288	0.965
0.45	0.679	0.968	0.402	0.344	0.968
0.46	0.729	0.973	0.404	0.413	0.970
0.47	0.766	0.977	0.406	0.496	0.972
0.48	0.795	0.976	0.408	0.559	0.973
0.49	0.817	0.972	0.41	0.586	0.975

Table 3: Impact of sample size; improved bounds on altruism $\bar{\pi}$ and inequality aversion $\bar{\delta}$ for different values of θ . Individual preferences are specified in (3) and (4) and the decision process in (7). In the columns Altruism and Inequality aversion we use, respectively, (5) and (6) to specify the preference parameters of individual 2.

model by their very construction (e.g. by using $\bar{\pi} = 0.976$ for $\theta = 0.48$ or $\bar{\pi} = 0.972$ for $\theta = 0.49$; see Table 3). We conclude that, when the preferences for altruism are strong enough, the associated behavior can no longer be interpreted as inequality averse.¹⁶ Finally, a similar conclusion holds when checking consistency of data generated by the inequality aversion model (specification (6)) with the testable implications of the altruism model: there exist such data sets (with θ sufficiently large) that do not satisfy the rationalization conditions for the altruism model.¹⁷

4 Joint decisions of children

Before we present our empirical results, we first explain our experimental design. In doing so, we will also motivate the empirical questions that we consider further on, with some additional references to the relevant literature. Subsequently, we discuss the main results of our empirical analysis. We find significant evidence that children’s joint consumption behavior is systematically characterized by consumption externalities (i.e. non-selfish behavior). Accounting for altruism (more than inequality aversion) particularly helps to rationalize the observed behavior of the children dyads in our sample. Interestingly, we also observe substantial variation in the degree of altruism over the different children in our sample. We

¹⁶Admittedly, for lower values of θ , it is not possible to identify the source of the other regarding preferences. This is due to the generality of our revealed preference conditions, which impose minimal parametric structure on the choice behavior under study. From this perspective, by restricting the class of preferences it will generally be easier to empirically distinguish between altruistic and inequality averse behavior. We leave this as a topic for future research.

¹⁷For compactness, we do not explicitly consider such a data set here. But it is available upon request.

relate this variation to observable child characteristics, and find that altruism bears particular relations to age, gender and the degree of friendship.

4.1 Experimental design

Respondents. We collected our data at four different schools. Our sample contains a total of 100 children, who belong to 3 different age categories: 42 from kindergarten, 24 from third grade and 34 from sixth grade. Table 4 presents some basic information for our sample in terms of gender composition and the degree of friendship (explained below). In what follows, we discuss the construction of our sample in more detail, and use this to position our following empirical analysis in the existing literature.

First of all, our sample allows us to link prosocial behavior to children’s age. There is some evidence that people in early childhood (aged below 5 years) are less altruistic (see, for example, Eisenberg et al. (2007) for a literature review on the development of prosocial behavior) and more likely to be driven by self-interest (see, for example, Damon (1980) on positive-justice). However, this does not automatically imply a stable and increasing relationship between age and prosocial behavior. On the one hand, Côté et al. (2002) found support for inter-individual stability in prosocial behavior. Similarly, Gummerum et al. (2008) did not find significant age effects on individual allocations in a dictator game. On the other hand, there is also evidence that young school children sometimes act less selfishly. See, for example, Murnighan and Saxon (1998) and Harbaugh et al. (2002), who found that younger children are more likely to accept smaller offers in ultimatum games, or Damon (1980), who found strong evidence of prosocial behavior by children between 5 and 7 years old.

In this respect, a particularly interesting study is the one of Fehr et al. (2013). These authors argue that, beyond the age of about 8 years, the increasing influence of efficiency considerations and strategic behavior may countervail fairness considerations. In a similar vein, it is claimed that the positive effects of a more prosocial orientation are offset by increasing levels of competitiveness as children grow older. Kagan and Madsen (1972) and Toda et al. (1978), for instance, have shown that the level of competition between children increases as a function of age. Summarizing, we may safely conclude that the literature does not show a clear consensus on the relationship between age and selfish preferences. This directly provides a particular motivation for our own empirical application. We deliver empirical input to the debate by considering prosocial behavior in the specific context of children’s group consumption decisions.

For each separate age category, we randomly organized the children into dyads, which we then invited to make 9 consumption choices. This resulted in 50 dyads and obtained information on 450 (= 50 x 9) joint decisions. We registered the gender composition of each dyad. There are 19 female dyads, 12 male dyads and 19 dyads consisting of one boy and one girl. Eisenberg et al. (2007) argued that girls are more prosocial than boys. Moreover, girls tend to be somewhat less competitively. Similar to before, our analysis will allow us to investigate this further in a specific consumption context.

Finally, we also registered the intensity of the dyad members’ relationship outside the experiment. In particular, we asked the children to label their relationship with respect to the other dyad member as “(very) strong friendship” or “weak (or no) friendship”. According

to Eisenberg et al. (2007), the literature suggests that children are more likely to share with friends than with less liked peers (see also Buhrmester et al. (1992) and Pilgrim and Rueda-Riedle (2002)). We will investigate this effect in a group consumption context.

		gender	
		boy	girl
grade	kindergarten	4 / 12 / 2	11 / 13 / 0
	thirdgrade	4 / 3 / 2	8 / 7 / 0
	sixthgrade	7 / 8 / 1	5 / 12 / 1

Table 4: Summary statistics on sample composition (x/y/z: x children who indicate (very) strong friendship with their dyad partner, y children who indicate weak (or no) friendship with their dyad partner, z children with missing values on the nature of the relationship)

Design. We invited the children dyads to solve nine successive decision problems. In order to simplify these decision problems, we follow Harbaugh, Krause, and Berry (2001) by defining discrete choice sets, which in our case consist of seven consumption bundles. These bundles are combinations of three nondurable and quickly consumable commodities: grapes (units of 10 grams), mandarins (units of 12.5 grams) and letter biscuits (units of 5 grams). Each choice set corresponds to a unique combination of (implicit) prices and budget: the seven bundles are discrete points on the corresponding budget hyperplane. The implicit budget was 24 in each choice problem, and we guaranteed sufficient price variation to obtain tests of our models with high discriminatory power.¹⁸

Our experiment was carried out in the classrooms of the four participating schools. We allowed the children to taste our three commodities prior to the experiment. It was emphasized that these “trial commodities” had the same taste and quality as the ones used in the choice problems. To motivate the children to truthfully reveal their preferences in their choice behavior, we told them that they would receive one of their chosen consumption bundles (randomly selected) after the experiment had ended.

For each choice problem, the actual experiment proceeded in two basic steps. In a first step, each dyad of children was asked to select one out of seven possible commodity bundles for the given (implicit) price and budget regimes. The children could take as much time as they wanted to make their joint decisions. In a second step, and in view of our following assessment of externalities, we asked each dyad to define individual shares of the joint consumption bundle that had been chosen, which means that we perfectly observe the shares of the (implicit) dyad budget allocated to each individual member. We provide more details on our experiment in Appendix C.

Table 5 reports summary statistics on the absolute intra-dyad differences between individual budget shares, which provides some basic insight into the intra-dyad sharing of resources. The table also gives the proportion of dyads that apply (close to) equal resource sharing (i.e. intra-dyad difference between individual resource shares amounts to less than 5 per cent of the available budget). We find that, on average, the resources are shared fairly equally, which actually also provides a specific motivation for our extension of the collective model with

¹⁸We refer to Appendix C for more details on the prices and discrete choice sets that we used.

	Obs	Mean	Std. Dev.	Min	Max	% Equal
all	50	0.064	0.064	0.001	0.29	56.00
kindergarten	21	0.099	0.081	0.004	0.29	33.33
third grade	12	0.029	0.018	0.001	0.06	91.67
sixth grade	17	0.046	0.032	0.004	0.122	58.82
weak friendship	30	0.077	0.076	0.001	0.29	46.67
strong friendship	17	0.048	0.034	0.001	0.122	64.71
two girls	19	0.067	0.065	0.001	0.29	52.63
mixed	19	0.063	0.055	0.001	0.18	52.63
two boys	12	0.062	0.078	0.004	0.29	66.67

Table 5: Intra-dyad budget sharing

inequality aversion. The mean absolute intra-dyad difference in shares amounts to 6.4 per cent. Interestingly, the difference is smallest for dyads containing third graders, while it is largest for dyads with kindergarten respondents. Similarly, we observe that sharing is more equal when children have a strong friendship relationship with their partner. Finally, the gender composition does not seem to have a strong impact on the resource sharing pattern.

Importantly, the goal of our empirical analysis extends beyond simply describing the sharing of resources. This observed sharing is the result of a within-dyad interaction process that is defined by individuals' preferences and bargaining positions. In the subsequent analysis, we investigate if externalities in consumption (altruism or inequality aversion) impact the decision processes that underlie the patterns summarized in Table 5.

4.2 Consumption with or without externalities

Pass rates. For a particular behavioral model (defined by a specific inequality aversion parameter δ or altruism parameter π), we compute the fraction of observed (dyad-specific) data sets that satisfy the corresponding rationalization conditions. We call this fraction our pass rate, which is situated between zero and one by construction. It measures the empirical fit of a given behavioral model. The interpretation is immediate: the better the model describes the observed behavior in our sample, the higher its pass rate will be. In this respect, it directly follows from our above discussion that the pass rate will increase monotonically when the parameters δ and π increase.

We begin our analysis by evaluating the empirical performance of the cooperative consumption model that we characterized in Corollary 1.2, for alternative values of the inequality aversion parameter δ . We recall that this parameter ranges from zero to one, with $\delta = 0$ indicating purely selfish behavior and $\delta = 1$ defining a least restrictive model that also accounts for the (opposite) scenario in which dyads positively value the consumption of one member *only* because it increases equality (and not for its direct impact of consumption on this member's utility). The associated pass rates are summarized in the first two columns in Table 6. We find that the model with $\delta = 0$, which corresponds to the purely selfish model, explains only 46 per cent of the observed dyads' behavior. By contrast, up to 78 per cent of the dyads' behavior is rationalized for $\delta = 1$. Thus, by allowing for unrestricted levels of inequality aversion, it is possible to rationalize 32 per cent more dyads.

We next consider the pass rates associated with the cooperative consumption model that we characterized in Corollary 1.1, for alternative values of the altruism parameter π . This parameter can again take any value between zero and one, with $\pi = 0$ indicating purely selfish behavior, and $\pi = 1$ corresponding to a least restrictive model that also includes the (opposite) scenario in which dyad members only care for the other’s consumption. We find that the choices of all dyads can be rationalized for $\pi = 1$. The altruism parameter allows us to describe all consumption choices in the sample. Related to this, there seems to be considerable heterogeneity in the degree of altruism across our sample of dyads, as pass rates are gradually increasing from $\pi = 0$ to $\pi = 1$.

Summarizing, these findings give substantial empirical support for consumption models that allow for deviations from purely selfish behavior. In this respect, our data seem to provide a stronger case for models with altruism than for models with inequality aversion. As shown in Appendix B, the two types of models are independent, so that we may take this as an indication that mainly altruism drives the observed deviations from the purely selfish consumption model.¹⁹ Moreover, the degree of “revealed altruism” varies considerably across dyads. In a following step (described in Section 4.3), we will investigate whether this observed variation bears specific relations to observable child characteristics.

δ	pass rate	π	pass rate
0	0.46	0	0.46
0.1	0.52	0.1	0.52
0.2	0.58	0.2	0.58
0.3	0.60	0.3	0.64
0.4	0.62	0.4	0.70
0.5	0.68	0.5	0.74
0.6	0.72	0.6	0.90
0.75	0.78	0.75	0.94
1	0.78	1	1

Table 6: Pass rates for different π and δ

Before studying the observed heterogeneity in children’s altruism in more detail, we evaluate the robustness of our findings summarized in Table 6. We consider the discriminatory power of the rationalizability conditions for the different models that we analyzed (with alternative values for π and δ). After all, a theoretical model has limited use if its behavioral implications have hardly any empirical bite.

¹⁹As an additional exercise, we have also computed pass rates for general models that simultaneously account for altruism and inequality aversion. We have already indicated in Section 2 that these models typically lead to a better *fit* of the data but with less *discriminatory power* (for more details on power, see *supra*), which makes them less well-suited to identify specific levels of altruism or inequality aversion. As an aside, we recall that the variables π and δ can be recovered from linear programming techniques in the special cases of altruistic and inequality averse preferences but not in a model in which one commodity is subject to both altruism and inequality aversion. The results in Appendix D confirm that the positive effect of higher pass rates is generally offset by the negative effect of lower discriminatory power in combined specifications.

Discriminatory power. In our above analysis, we have presented a continuum of models, where higher values of δ and π allow for more consumption externalities. Thus, by construction we will have that higher values for δ and π lead to less restrictive consumption models, which makes it easier to pass the corresponding revealed preference conditions. To account for this trade-off between economic realism (i.e. permit deviations from purely selfish behavior) and restrictiveness, a fair comparison of models with different values for δ and π should simultaneously account for both their empirical fit (i.e. whether or not the data satisfy the associated rationalization conditions) and their discriminatory power (i.e. the extent to which these rationalization conditions can effectively identify irrational behavior). Ideally, a behavioral model combines a good empirical fit with high discriminatory power. See Beatty and Crawford (2011) for a general discussion of this point.

To measure the discriminatory power of a behavioral model, we make use of Bronars (1987)’s power index. This index is based on Becker (1962)’s notion of irrational behavior, i.e. behavior that randomly exhausts the available budget. In our application, we mimic such irrational behavior by randomly sampling from a uniform distribution on the choice sets. In a next step, we randomly allocate the simulated consumption per good among the dyad members. In this way we reconstruct artificial consumption bundles (and the corresponding allocation) for each observed budget set.²⁰ We repeat this procedure 5,000 times, which thus defines 5,000 sets of T “irrational” consumption choices. Bronars’ power index equals one minus the fraction of these artificial data sets that pass the rationalization conditions under evaluation. This index will be situated between zero and one. It proxies the probability that the (null) hypothesis of rationality (i.e. consistency with the model) is rejected when the alternative hypothesis (i.e. choices are drawn randomly from a uniform distribution) holds. A high index value signals that the conditions can successfully discriminate between rational and irrational (random) behavior.

In our application, we compute a separate power index for every different dyad. To obtain these dyad-specific indices, we first identify the minimum values of δ (for inequality aversion) and π (for altruism) that allow us to rationalize the observed consumption behavior. Intuitively, these minimum values correspond to minimal deviations from the purely selfish consumption model. Then, we compute the dyad-specific power indices by using the above procedure for these minimal δ - and π -values. As such, our power assessment gives information on the expected distribution of violations under random choice, while incorporating information on the dyads’ actual choices. Table 7 summarizes our results for these dyad-specific indices. It reports the average values of the power indices over the subsamples of dyads of which the observed behavior can be rationalized for alternative levels of inequality aversion (δ) and altruism (π).²¹

²⁰At this point, it is worth noting that there are several alternatives for defining the power index (see Andreoni et al. (2013) for an overview). The most notable alternative is the bootstrap power, which simulates random bundles by drawing budget shares from the distribution of observed choices (instead of the uniform distribution). As a robustness check, we also used this power measure for our data. For compactness, we do not discuss the results here, but the associated results are qualitatively similar to the ones given in Table 7.

²¹We focus on subsamples with rationalizable behavior for the given δ - and π -values because the corresponding pass rates are equal to one by construction. This gives a natural interpretation to the average power indices in Table 7: deviations from one equal the difference between the pass rate for actual behavior and the pass rate for (simulated) random behavior.

δ	power	π	power
0	0.97	0	0.97
0.1	0.95	0.1	0.94
0.2	0.93	0.2	0.89
0.3	0.91	0.3	0.86
0.4	0.89	0.4	0.83
0.5	0.88	0.5	0.81
0.6	0.87	0.6	0.79
0.75	0.85	0.75	0.77
1	0.84	1	0.75

Table 7: Discriminatory power (π altruism, δ inequality aversion)

We find that the standard model with purely selfish consumers is indeed a very stringent one, as it is characterized by an average power index of about 0.97. In other words, (simulated) irrational behavior passes the associated rationalization conditions in less than 3 per cent of the cases. Generally, we observe that the rationalization conditions become more permissive if we leave more room for consumption externalities (i.e. more non-selfish behavior, as characterized by higher values of δ and π). However, the average power index is nowhere below 0.75. In other words, even in the most permissive scenario (with $\pi = 1$) the tests can still reject rationalizability for about 75 per cent of the random data sets. The average power index for the least restrictive inequality aversion model (with $\delta = 1$) amounts to 0.84.

Generally, we may conclude that all the models that we investigated do have rationalizability conditions with substantial discriminatory power. Although there is a drop in the power for the altruism model, this does not seem to be enough to explain the much bigger increase in the corresponding pass rates. This suggests that the favorable results in Table 6 for the models with non-selfish individuals (particularly the altruism models) are not simply explained by low power.

4.3 Altruism and child characteristics

As argued above, our results provide substantial support for models with altruism. Moreover, there appears to be quite some variation in altruism across the dyads in our sample. We next relate this inter-dyad heterogeneity to observable child characteristics. In particular, we consider children’s age, gender and the reported level of intra-dyad friendship.

To address this question, we follow a similar procedure as in our simulation analysis in Section 3. Specifically, we compute a lower bound on the degree of altruism in each dyad h , which we denote as π^h . For a given data set on dyad consumption choices, we minimize π^h subject to the given rationalization conditions. Basically, this computes the minimal degree of altruism that we need to account for in order to rationalize the observed dyad behavior in terms of the cooperative model.²² Larger values of π^h indicate that consistency with

²²We restrict attention to dyad-specific levels of π . In theory, our tests can perfectly deal with individual-

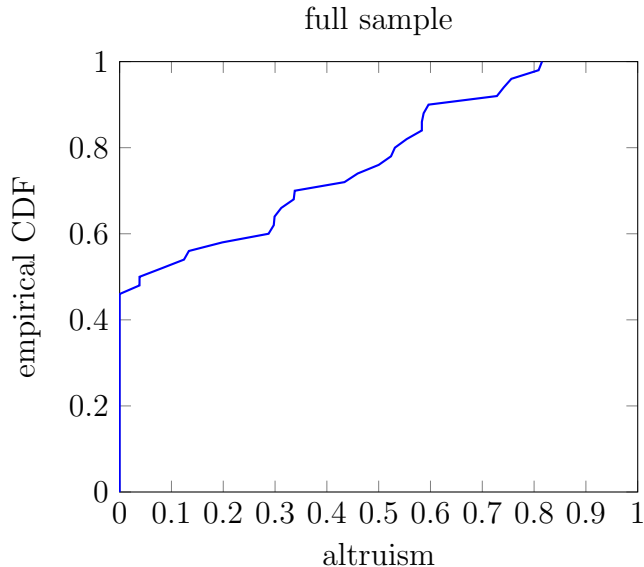


Figure 1: Cumulative distribution of the altruism parameter; whole sample

cooperative group behavior requires greater deviations from purely selfish behavior.

Using this procedure, we can compute an altruism parameter π^h for each different dyad h in our sample. Figure 1 presents the distribution of this altruism parameter for the 50 dyads in our experiment. Consistent with our findings in Table 6, for 46 per cent of the dyads h the value of π^h equals zero. For the remaining children, we need to account for strictly positive levels of altruism to rationalize the observed consumption behavior. Actually, we observe that the cumulative distribution curve is increasing up to π^h as high as 0.8, which reveals a high degree of altruism. Generally, the distribution pattern in Figure 1 effectively reveals considerable heterogeneity in the degree of altruism.

Comparing dyad groups. We first consider how friendship relates to altruism. In particular, we distinguish between two types of dyads: dyads in which children report a (very) strong friendship with their dyad partner, and dyads in which children report a weak (or no) friendship. Our results are displayed in Figure 2. While the two cumulative distribution functions are quite similar for lower degrees of altruism, there is a clear dominance relation for higher levels of altruism. Specifically, for children who are non-selfish, the degree of altruism in behavior is systematically higher when they consider their partners to be strong friends. This indicates that intra-dyad friendship effectively does increase the level of altruism; non-selfish children are willing to contribute more to their friends' material consumption. This is exactly what can be expected from friends, and falls in line with the literature (see, for example, Buhrmester et al. (1992), Pilgrim and Rueda-Riedle (2002) and

specific levels π^1 and π^2 (i.e. $\mathbf{p}_t^{m,l} \leq \pi^m \mathbf{p}_t$). However, the “optimal” values for π^1 and π^2 will crucially depend on how π^1 and π^2 are aggregated. For example, minimizing $\pi^1 + \pi^2$ implicitly assumes that π^1 and π^2 are perfectly substitutable. Furthermore, our use of a uniform bound π for the two dyad members clearly does allow for unequal personalized prices within dyads.

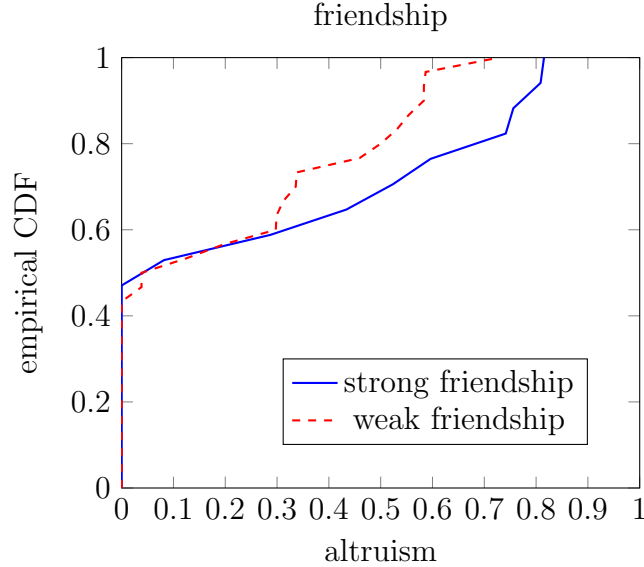


Figure 2: Cumulative distribution of the altruism parameter; strong friendship versus weak friendship

Eisenberg et al. (2007)). In a sense, this also indicates that our methodology effectively does produce a sensible measure of altruism.

Next, we turn to the gender effect, for which the relevant results are given in Figure 3. We compare the distribution of the degree of altruism for dyads containing only boys and dyads containing at least one girl. In this case, there is no clear first order stochastic dominance relation between the π^h scores for dyads that exclusively contain boys and dyads with girls. However, the results do indicate that the probability of *purely* selfish behavior ($\pi^h = 0$) is considerably larger for all boys dyads. As discussed above, this falls in line with reported evidence that girls generally do tend to act more prosocially (and less competitively).

Finally, we consider the age effect, for which there appeared to be no clear consensus in the literature. The results are summarized in Figure 4. A first observation here is that there is no first order stochastic dominance relation between the π^h scores for kindergarten respondents and third graders. Next, we also find that sixth graders are generally less altruistic than younger children (both kindergarten children and third graders), who seem to be characterized by larger consumption externalities.

At first glance, these results may seem to contradict the conclusion of Eisenberg et al. (2007), which indicates a positive relationship between age and prosocial behavior. In this respect, however, we also recall that around the age of eight years (i.e. third grade) there is a peak in elementary prosocial behavior. Moreover, we also argued that incidences of competitiveness between children and strategic behavior appear to increase with age (see, for example, Kagan and Madsen (1972) and Toda et al. (1978)). As such, our results provide further input to this interesting debate, by focusing on the specific setting of joint consumption decisions. At a more general level, this also motivates the practical usefulness of our methodology.

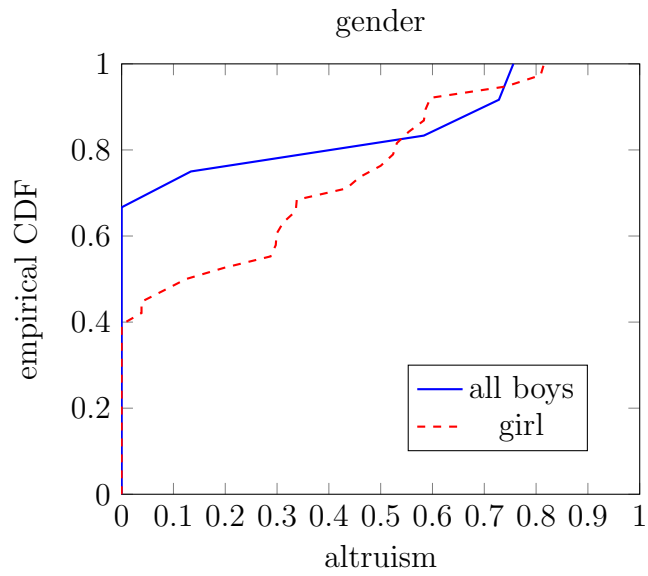


Figure 3: Cumulative distribution of the altruism parameter; boys versus girls

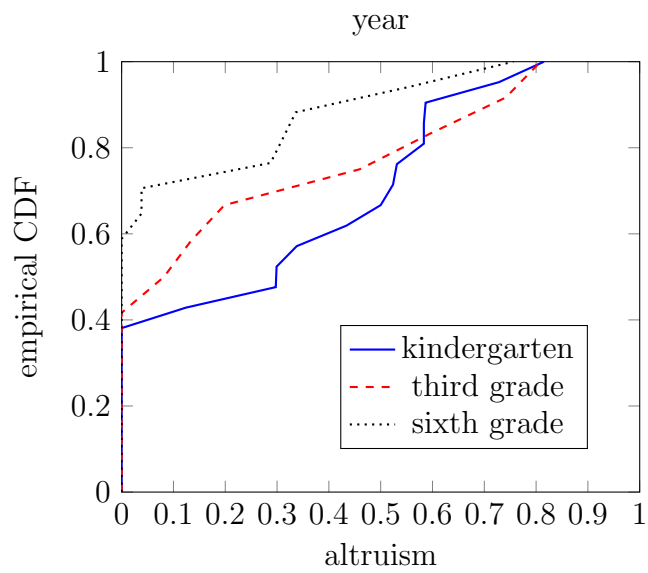


Figure 4: Cumulative distribution of the altruism parameter; kindergarten, third grade and sixth grade

Statistical significance. To verify the statistical meaning of our above conclusions, we carried out Wilcoxon ranksum tests (or Mann-Whitney U tests). The ranksum tests were applied to the entire sample (all dyads) as well as to the (smaller) subsample of dyads for which π^h is strictly positive. The motivation for the latter exercise is that the factors that allow us to discriminate between selfishness and altruism may differ from the factors that govern the precise level of altruism in non-selfish dyads. Related to this, our results in Figure 2 already indicated that the proportion of altruistic (vis-à-vis selfish) dyads is relatively robust to the level of friendship in the dyad, while, at the same time, the level of altruism in non-selfish dyads seems higher among friends.

Basically, each of our exercises compares two populations. The null hypothesis is that two populations have the same distribution for our altruism parameter π . Correspondingly, the alternative hypothesis is that one of the populations systematically has higher values for the parameter than the other. The results of our Wilcoxon tests are given in Table 8.

We find that two effects are statistically significant. First, across all dyads, kindergarten respondents and third graders have a higher rank sum than expected under the null hypothesis, whereas sixth graders have a lower rank sum than expected. Correspondingly, we reject the hypothesis that π is equally distributed for the two groups (i.e. kindergarten respondents and third graders versus sixth graders). Second, for non-selfish dyads, we also observe that dyads in which children are good friends are characterized by higher levels of altruism. These results statistically confirm the patterns in Figures 2 and 4.

Ranksum		all dyads			dyads with $\pi^h > 0$		
		rank sum	expected	P-value	rank sum	expected	P-value
age	0 kind.,thirdg.	920	841.5		304	280	
	1 sixthg.	355	433.5		74	98	
	Combined	1275	1275	0.0906	378	378	0.1842
friendship	0 weak	1015	969		196	229.5	
	1 strong	260	306		155	121.5	
	Combined	1275	1275	0.2715	351	351	0.0710
gender	0 girls	696	720		306	322	
	1 boys	432	408		72	56	
	Combined	1128	1128	0.5777	378	378	0.2748

Table 8: Ranksum tests

5 Conclusion

We discussed how to extend the purely selfish model of group consumption behavior by imposing specific structure on patterns of altruism and inequality aversion. Importantly, this generalizes the selfish model in two distinctively different directions. We have shown that altruism and inequality aversion models are independent in terms of empirical implications: consumption behavior that fits one model needs not necessarily fit the other model. Intuitively, the explanation is that inequality aversion allows for negative consumption externalities, which is excluded in the case of altruism. It makes that we can separately investigate

the implications of the two types of prosocial behavior for group consumption decisions.

Next, we have introduced a revealed preference method to quantify the willingness-to-pay for the consumption of others, as well as the willingness-to-pay for consumption equality. Within the framework of the cooperative (i.e. Pareto efficient) consumption model, we measure willingness-to-pay for others' consumption by evaluating consumption externalities in monetary terms. Interestingly, the method allows us to define an altruism parameter and an inequality aversion parameter. Each of these parameters characterizes a continuum of models with varying degrees of consumption externalities.

Furthermore, we assessed the empirical performance of our method through a simulation analysis that used a specific parametrization of the individual preferences and the bargaining process. We found that the altruism and inequality aversion parameters that we recover provide good approximations of the true parameters when the externalities are sufficiently strong. We also demonstrated that our estimates are robust to measurement errors, and that increased sample sizes (yielding additional price variation) may substantially improve the power of our method.

Finally, we have shown the practical usefulness of our method by an application to consumption choices made by dyads of children. We find that children's consumption decisions are systematically characterized by externalities (i.e. non-selfish preferences). In particular, for our sample of children, we find strong support for altruism models (more than for inequality aversion models). Interestingly, we also observed substantial heterogeneity across children in the degree of altruism, which we related to differences in age, gender and degree of friendship between dyad members. For our sample, we found that sixth graders behave less altruistically than third graders and kindergarten children. Furthermore, children tend to act more altruistically in joint consumption decisions when they have a strong friendship with the other group members.

We see several avenues for further research. At the methodological level, we can extend our revealed preference characterizations to other types of social (or other-regarding) preferences (see, for example, Sobel (2005) for a recent review). For example, we could use our revealed preference approach to devise testable implications of alternative models that define particular origins of positive and/or negative externalities (including envy). This can be used to investigate whether different models are empirically distinguishable from each other in revealed preference terms. And, if so, we can relate the applicability of specific models to the (observable) characteristics of the individuals at hand.

At the empirical level, our application has used data that we collected through a specially designed consumption experiment. This experiment clearly showed the potential of our approach to empirically explore relations between non-selfish behavior and individual characteristics. In this first study we used only a fairly limited amount of information on observed characteristics (i.e. age, gender and friendship). Obviously, richer data sets (also including more observations) can obtain a more detailed analysis of the drivers of externalities. For example, this may imply a deeper investigation of the relationship between age and non-selfishness.

Finally, in this study we used experimental data because our focus was on children's consumption. However, our revealed preference methodology can also be used in combination with observational data. For example, an interesting application may identify the degree of consumption externalities in household consumption, and relate inter-household hetero-

generosity in our altruism and inequality aversion parameters to specific household (member) characteristics. In this respect, we can also refer to Cherchye et al. (2009, 2011) for empirical studies of household consumption behavior that make use of revealed preference methods similar to ours.

Interestingly, data sets with detailed information on the intra-household consumption allocation are increasingly available. Notable examples are the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel and the Japanese Panel Survey of Consumers (JPSC). See, for example, Cherchye et al. (2012) for an application of the cooperative model to the LISS data, and Lise and Yamada (2014) for an application to the JPSC data. These studies focus on households' time use allocations (including the supply of home and market labor) and the associated trade-off between consumption and leisure, hereby exploiting wage variation as a prime source of price variation. Given that our methodology can attach different levels of altruism and/or inequality aversion to different commodities, it is possible to compare the intra-household externalities generated by leisure and private consumption, respectively.

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A Proof and implementation of Proposition 2

A.1 Proof of Proposition 2

We prove the equivalence between a cooperative rationalization under π -altruism and δ -inequality aversion and the corresponding revealed preference characterization in Proposition 2.

Necessity. We show that statement 1 implies statement 2, i.e. the existence of a pair of utility functions U^1 and U^2 that provide a cooperative rationalization under π -altruism and δ -inequality aversion implies that there exist non-negative price vectors $\mathbf{p}_t^{1,1}$, $\mathbf{p}_t^{2,2}$, $\mathbf{p}_t^{1,2}$, $\mathbf{p}_t^{2,1}$, $\mathbf{p}_t^{1,d}$ and $\mathbf{p}_t^{2,d}$ such that the subsets $S^1 = \{(\mathbf{p}_t^{1,1}, \mathbf{p}_t^{1,2}, \mathbf{p}_t^{1,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ and $S^2 = \{(\mathbf{p}_t^{2,1}, \mathbf{p}_t^{2,2}, \mathbf{p}_t^{2,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ are both consistent with the GARP and such that the conditions on these price vectors hold.

First, we derive the first-order conditions associated with the optimization problem in Definition 3:

$$\begin{aligned}\mu_t^1 \frac{\partial U^1}{\partial q_{t,j}^1} + \mu_t^2 \frac{\partial U^2}{\partial q_{t,j}^1} + (\mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}}) \frac{\partial d_j}{\partial q_{t,j}^1} &\leq \lambda_t p_{t,j}, \\ \mu_t^2 \frac{\partial U^2}{\partial q_{t,j}^2} + \mu_t^1 \frac{\partial U^1}{\partial q_{t,j}^2} + (\mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}}) \frac{\partial d_j}{\partial q_{t,j}^2} &\leq \lambda_t p_{t,j},\end{aligned}$$

with $\frac{\partial d_j}{\partial q_{t,j}^m}$, $\frac{\partial U^m}{\partial \mathbf{q}_t^m}$, $\frac{\partial U^l}{\partial \mathbf{q}_t^m}$ and $\frac{\partial U^l}{\partial \mathbf{d}_t}$ ($m, l = 1, 2, m \neq l$) the supergradients of the functions U^1 and U^2 with respect to \mathbf{q}_t^m and \mathbf{d}_t , all evaluated at $(\mathbf{q}_t^1, \mathbf{q}_t^2)$. At this point, we can define personalized prices as follows:

$$\begin{aligned}\mathbf{p}_t^{1,2} &= \frac{\mu_t^1 \partial U^1}{\lambda_t \partial \mathbf{q}_t^2}, \mathbf{p}_t^{2,1} = \frac{\mu_t^2 \partial U^2}{\lambda_t \partial \mathbf{q}_t^1}, \\ \mathbf{p}_t^{1,d} &= \frac{\mu_t^1 \partial U^1}{\lambda_t \partial \mathbf{d}_t}, \mathbf{p}_t^{2,d} = \frac{\mu_t^2 \partial U^2}{\lambda_t \partial \mathbf{d}_t},\end{aligned}$$

$$\begin{aligned}p_{t,j}^{1,1} &= p_{t,j} - \frac{\mu_t^2 \partial U^2}{\lambda_t \partial q_{t,j}^1} - (\mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}}) \frac{\partial d_j}{\partial q_{t,j}^1}, \\ p_{t,j}^{2,2} &= p_{t,j} - \frac{\mu_t^1 \partial U^1}{\lambda_t \partial q_{t,j}^2} - (\mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}}) \frac{\partial d_j}{\partial q_{t,j}^2}.\end{aligned}$$

This obtains that $p_{t,j}^{1,1} + p_{t,j}^{2,1} + (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \frac{\partial d_j}{\partial q_{t,j}^1} = p_{t,j} = p_{t,j}^{1,2} + p_{t,j}^{2,2} + (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \frac{\partial d_j}{\partial q_{t,j}^2}$, which gives Condition (b) (note that given our definition of $d(\cdot)$ we have that $\frac{\partial d_j}{\partial q_{t,j}^m} = 1$ if $q_{t,j}^m < q_{t,j}^l$ and $\frac{\partial d_j}{\partial q_{t,j}^m} = -1$ if $q_{t,j}^m \geq q_{t,j}^l$). Moreover, the above shows that

$$\mathbf{p}_t^{1,1} \geq \frac{\mu_t^1 \partial U^1}{\lambda_t \partial \mathbf{q}_t^1}, \mathbf{p}_t^{2,2} \geq \frac{\mu_t^2 \partial U^2}{\lambda_t \partial \mathbf{q}_t^2}.$$

Second, we use that the individual utility functions are concave. As such,

$$\begin{aligned}U^1(\mathbf{q}_s^1, \mathbf{q}_s^2, \mathbf{d}_s) - U^1(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) &\leq \frac{\partial U^{1'}}{\partial \mathbf{q}_t^1} (\mathbf{q}_s^1 - \mathbf{q}_t^1) + \frac{\partial U^{1'}}{\partial \mathbf{q}_t^2} (\mathbf{q}_s^2 - \mathbf{q}_t^2) \\ &\quad + \frac{\partial U^{1'}}{\partial \mathbf{d}_t} (\mathbf{d}_s - \mathbf{d}_t), \\ U^2(\mathbf{q}_s^2, \mathbf{q}_s^1, \mathbf{d}_s) - U^2(\mathbf{q}_t^2, \mathbf{q}_t^1, \mathbf{d}_t) &\leq \frac{\partial U^{2'}}{\partial \mathbf{q}_t^2} (\mathbf{q}_s^2 - \mathbf{q}_t^2) + \frac{\partial U^{2'}}{\partial \mathbf{q}_t^1} (\mathbf{q}_s^1 - \mathbf{q}_t^1) \\ &\quad + \frac{\partial U^{2'}}{\partial \mathbf{d}_t} (\mathbf{d}_s - \mathbf{d}_t).\end{aligned}$$

By taking $\eta_t^m = \frac{\lambda_t}{\mu_t^m}$, and given the definitions of $\mathbf{p}_t^{1,1}$, $\mathbf{p}_t^{2,2}$, $\mathbf{p}_t^{1,2}$, $\mathbf{p}_t^{2,1}$, $\mathbf{p}_t^{1,d}$ and $\mathbf{p}_t^{2,d}$, we then effectively obtain

$$\begin{aligned} U^1(\mathbf{q}_s^1, \mathbf{q}_s^2, \mathbf{d}_s) - U^1(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) &\leq \eta_t^1 \mathbf{p}_t^{1,1'} (\mathbf{q}_s^1 - \mathbf{q}_t^1) \\ &\quad + \eta_t^1 \mathbf{p}_t^{1,2'} (\mathbf{q}_s^2 - \mathbf{q}_t^2) + \eta_t^1 \mathbf{p}_t^{1,d'} (\mathbf{d}_s - \mathbf{d}_t), \\ U^2(\mathbf{q}_s^2, \mathbf{q}_s^1, \mathbf{d}_s) - U^2(\mathbf{q}_t^2, \mathbf{q}_t^1, \mathbf{d}_t) &\leq \eta_t^2 \mathbf{p}_t^{2,2'} (\mathbf{q}_s^2 - \mathbf{q}_t^2) \\ &\quad + \eta_t^2 \mathbf{p}_t^{2,1'} (\mathbf{q}_s^1 - \mathbf{q}_t^1) + \eta_t^2 \mathbf{p}_t^{2,d'} (\mathbf{d}_s - \mathbf{d}_t). \end{aligned}$$

Taking $U^m(\mathbf{q}_s^m, \mathbf{q}_s^l, \mathbf{d}_s) = U_s^m$ results exactly into the Afriat inequalities applied to our framework. Varian (1982) proved the equivalence between consistency with the Afriat inequalities and consistency with the GARP. Hence, we have shown that the data set must be such that $S^1 = \{(\mathbf{p}_t^{1,1}, \mathbf{p}_t^{1,2}, \mathbf{p}_t^{1,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ and $S^2 = \{(\mathbf{p}_t^{2,1}, \mathbf{p}_t^{2,2}, \mathbf{p}_t^{2,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ are both consistent with the GARP. This gives Condition (a).

Next, to show Condition (d), we derive

$$\begin{aligned} \mu_t^l \frac{\partial U^l}{\partial q_{t,j}^m} &\leq \varepsilon \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right) \\ &\Rightarrow p_t^{l,m} \leq \varepsilon p_t^{m,m} \\ &\Rightarrow (1 + \varepsilon) p_t^{l,m} \leq \varepsilon (p_t^{m,m} + p_t^{l,m}) \\ &\Rightarrow p_t^{l,m} \leq \pi (p_t^{m,m} + p_t^{l,m}). \end{aligned}$$

Finally, Condition (c) follows from

$$\begin{aligned} \mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}} &\leq \gamma_{t,j}^m \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right) \\ &\Rightarrow p_{t,j}^{1,d} + p_{t,j}^{2,d} \leq \gamma_{t,j}^m p_{t,j}^{m,m} \\ &\Rightarrow (1 + \gamma_{t,j}^m \frac{\partial d_j}{\partial q_{t,j}^m}) (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \leq \gamma_{t,j}^m (p_{t,j}^{m,m} + \frac{\partial d_j}{\partial q_{t,j}^m} (p_{t,j}^{1,d} + p_{t,j}^{2,d})) \\ &\Rightarrow p_{t,j}^{1,d} + p_{t,j}^{2,d} \leq \delta \left(p_{t,j}^{m,m} + \frac{\partial d_j}{\partial q_{t,j}^m} (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \right). \end{aligned}$$

Sufficiency. First, Condition (a) implies that both data sets S^1 and S^2 must be consistent with the GARP. From Varian (1982), we know that consistency of $S^1 = \{(\mathbf{p}_t^{1,1}, \mathbf{p}_t^{1,2}, \mathbf{p}_t^{1,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ and $S^2 = \{(\mathbf{p}_t^{2,1}, \mathbf{p}_t^{2,2}, \mathbf{p}_t^{2,d}; \mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t); t = 1, \dots, T\}$ with GARP is equivalent to the existence of utility numbers u_t^m and Lagrange multipliers η_t^m such that for $m, l = 1, 2$:

$$\begin{aligned} u_s^m - u_t^m &\leq \eta_t^m \mathbf{p}_t^{m,m'} (\mathbf{q}_s^m - \mathbf{q}_t^m) + \eta_t^m \mathbf{p}_t^{m,l'} (\mathbf{q}_s^l - \mathbf{q}_t^l) \\ &\quad + \eta_t^m \mathbf{p}_t^{m,d'} (\mathbf{d}_s - \mathbf{d}_t). \end{aligned}$$

By using these Afriat-like inequalities, we can construct utility functions U^1 and U^2 that rationalize the observed data. For any pair of quantity vectors $(\mathbf{z}^1, \mathbf{z}^2)$ (with $d_j = -|z_j^1 - z_j^2|$) we can define (for $m = 1, 2$)

$$U^m(\mathbf{z}^1, \mathbf{z}^2, \mathbf{d}) = \min_{s \in \{1, \dots, T\}} [U_s^m + \eta_s^m [(\mathbf{p}_s^{m,1'} \mathbf{z}^1 + \mathbf{p}_s^{m,2'} \mathbf{z}^2 + \mathbf{p}_s^{m,d'} \mathbf{d}) - (\mathbf{p}_s^{m,1'} \mathbf{q}_s^1 + \mathbf{p}_s^{m,2'} \mathbf{q}_s^2 + \mathbf{p}_s^{m,d'} \mathbf{d}_s)]].$$

Let us show that these utility functions effectively provide a cooperative rationalization under π -altruism and δ -inequality aversion. First of all, Varian (1982) has proven that the utility functions are well-behaved and that $U^m(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) = U_t^m$. Then, for strictly positive μ_t^m , we can simply add up the utility functions of different group members and obtain the following condition:

$$\sum_{m,l=1,2,m \neq l} \mu_t^m U^m(\mathbf{z}^m, \mathbf{z}^l, \mathbf{d}) \leq \sum_{m,l=1,2,m \neq l} \mu_t^m [U_t^m + \eta_t^m [(\mathbf{p}_t^{m,m'} \mathbf{z}^m + \mathbf{p}_t^{m,l'} \mathbf{z}^l + \mathbf{p}_t^{m,d'} \mathbf{d}) - (\mathbf{p}_t^{m,m'} \mathbf{q}_t^m + \mathbf{p}_t^{m,l'} \mathbf{q}_t^l + \mathbf{p}_t^{m,d'} \mathbf{d}_t)]].$$

For the remainder of the proof, we set $\mu_t^m = 1/\eta_t^m$ and thus we have

$$\sum_{m,l=1,2,m \neq l} \mu_t^m U^m(\mathbf{z}^m, \mathbf{z}^l, \mathbf{d}) \leq \sum_{m,l=1,2,m \neq l} \mu_t^m U_t^m + [(\mathbf{p}_t^{m,m'} \mathbf{z}^m + \mathbf{p}_t^{m,l'} \mathbf{z}^l + \mathbf{p}_t^{m,d'} \mathbf{d}) - (\mathbf{p}_t^{m,m'} \mathbf{q}_t^m + \mathbf{p}_t^{m,l'} \mathbf{q}_t^l + \mathbf{p}_t^{m,d'} \mathbf{d}_t)].$$

Take any $(\mathbf{z}^1, \mathbf{z}^2)$ that satisfy $\mathbf{p}'_t \mathbf{z}^1 + \mathbf{p}'_t \mathbf{z}^2 \leq \mathbf{p}'_t \mathbf{q}_t^1 + \mathbf{p}'_t \mathbf{q}_t^2$. We can rewrite the terms $(p_{t,j}^{1,1} z_j^1 + p_{t,j}^{1,2} z_j^2) - (p_{t,j}^{1,1} q_{t,j}^1 + p_{t,j}^{1,2} q_{t,j}^2) + (p_{t,j}^{2,2} z_j^2 + p_{t,j}^{2,1} z_j^1) - (p_{t,j}^{2,2} q_{t,j}^2 + p_{t,j}^{2,1} q_{t,j}^1) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j})$ as follows:

$$\begin{aligned} & (p_{t,j}^{1,1} z_j^1 + p_{t,j}^{1,2} z_j^2) - (p_{t,j}^{1,1} q_{t,j}^1 + p_{t,j}^{1,2} q_{t,j}^2) + (p_{t,j}^{2,2} z_j^2 + p_{t,j}^{2,1} z_j^1) - (p_{t,j}^{2,2} q_{t,j}^2 + p_{t,j}^{2,1} q_{t,j}^1) \\ & + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j}) \\ = & (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j}). \end{aligned}$$

Case 1 Suppose that $q_{t,j}^1 > q_{t,j}^2$:

$$\begin{aligned} & (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j}) \\ \leq & (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) \\ & + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^2 - q_{t,j}^2) - (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^1 - q_{t,j}^1) \\ \leq & p_{t,j}(z_j - q_j). \end{aligned} \tag{8}$$

The first inequality follows from the definition of $d(\cdot)$, the second inequality follows from the Condition (b) that $p_{t,j}^{1,1} + p_{t,j}^{2,1} - p_{t,j}^{1,d} - p_{t,j}^{2,d} = p_{t,j}$ and $p_{t,j}^{1,2} + p_{t,j}^{2,2} + p_{t,j}^{1,d} + p_{t,j}^{2,d} = p_{t,j}$.

Case 2 Suppose that $q_{t,j}^1 = q_{t,j}^2$:

$$\begin{aligned}
& (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j}) \\
& \leq (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) \\
& \quad - (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^2 - q_{t,j}^2) - (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^1 - q_{t,j}^1) \\
& \leq p_{t,j}(z_j - q_j). \tag{9}
\end{aligned}$$

The first inequality follows from the definition of $d(\cdot)$, the second inequality follows from the Condition (b) that $p_{t,j}^{1,1} + p_{t,j}^{2,1} - p_{t,j}^{1,d} - p_{t,j}^{2,d} = p_{t,j}$ and $p_{t,j}^{1,2} + p_{t,j}^{2,2} - p_{t,j}^{1,d} - p_{t,j}^{2,d} = p_{t,j}$.

Case 3 Suppose that $q_{t,j}^1 < q_{t,j}^2$:

$$\begin{aligned}
& (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(d_j - d_{t,j}) \\
& \leq (p_{t,j}^{1,1} + p_{t,j}^{2,1})(z_j^1 - q_{t,j}^1) + (p_{t,j}^{2,2} + p_{t,j}^{1,2})(z_j^2 - q_{t,j}^2) \\
& \quad - (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^2 - q_{t,j}^2) + (p_{t,j}^{1,d} + p_{t,j}^{2,d})(z_j^1 - q_{t,j}^1) \\
& \leq p_{t,j}(z_j - q_j). \tag{10}
\end{aligned}$$

The first inequality follows from the definition of $d(\cdot)$, the second inequality follows from the Condition (b) that $p_{t,j}^{1,1} + p_{t,j}^{2,1} + p_{t,j}^{1,d} + p_{t,j}^{2,d} = p_{t,j}$ and $p_{t,j}^{1,2} + p_{t,j}^{2,2} - p_{t,j}^{1,d} - p_{t,j}^{2,d} = p_{t,j}$.

Summing over all goods (i.e. summing the expressions 8 – 10), we obtain $\mathbf{p}'_t \mathbf{z}^1 + \mathbf{p}'_t \mathbf{z}^2 - \mathbf{p}'_t \mathbf{q}_t^1 - \mathbf{p}'_t \mathbf{q}_t^2$, which is smaller than zero due to the budget constraint. Hence, we obtain

$$\sum_{m,l=1,2,m \neq l} \mu_t^m U^m(\mathbf{z}^m, \mathbf{z}^l) \leq \sum_{m,l=1,2,m \neq l} \mu_t^m U_t^m = \sum_{m,l=1,2,m \neq l} \mu_t^m U(\mathbf{q}_t^m, \mathbf{q}_t^l, \mathbf{d}_t).$$

This shows that $(\mathbf{q}_t^1, \mathbf{q}_t^2)$ maximizes the group's objective function subject to $\mathbf{p}'_t \mathbf{z}^1 + \mathbf{p}'_t \mathbf{z}^2 \leq \mathbf{p}'_t \mathbf{q}_t^1 + \mathbf{p}'_t \mathbf{q}_t^2$. As such, we have constructed a pair of utility functions that cooperatively rationalizes the data under π -altruism and δ -inequality aversion.

To finish the proof, we show that our constructed utility functions satisfy Conditions (1) and (2) in Definition 3. Towards this end, we use Conditions (c) and (d) from Proposition 2.

$$\begin{aligned}
p_{t,j}^{l,m} & \leq \pi(p_{t,j}^{m,m} + p_{t,j}^{l,m}) \text{ and } \varepsilon = \frac{\pi}{1 - \pi} \\
& \Rightarrow \varepsilon \geq \frac{p_{t,j}^{l,m}}{p_{t,j}^{m,m}}
\end{aligned}$$

Using $\frac{\partial U^m}{\partial q_{t,j}^m} \leq \eta_t^m p_t^{m,m}$, $\frac{\partial U^l}{\partial q_{t,j}^m} \leq \eta_t^l p_t^{l,m}$ and (without loss of generality) $\mu_t^m = 1/\eta_t^m$, we obtain that

$$\begin{aligned}
\varepsilon &\geq \frac{\frac{1}{\eta_t^l} \frac{\partial U^l}{\partial q_{t,j}^m}}{\frac{1}{\eta_t^m} \frac{\partial U^m}{\partial q_{t,j}^m}} \\
&\Rightarrow \varepsilon \geq \frac{\mu_t^l \frac{\partial U^l}{\partial q_{t,j}^m}}{\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m}} \\
&\Rightarrow \varepsilon \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right) \geq \mu_t^l \frac{\partial U^l}{\partial q_{t,j}^m}.
\end{aligned}$$

By a similar reasoning,

$$\begin{aligned}
p_{t,j}^{1,d} + p_{t,j}^{2,d} &\leq \delta \left(p_{t,j}^{m,m} + \frac{\partial d_j}{\partial q_{t,j}^m} (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \right) \text{ and } \gamma_{t,j}^m = \frac{\delta}{1 - \delta \frac{\partial d_j}{\partial q_{t,j}^m}} \\
&\Rightarrow \gamma_{t,j}^m \geq \frac{p_{t,j}^{1,d} + p_{t,j}^{2,d}}{p_{t,j}^{m,m}} = \frac{\frac{1}{\eta_t^1} \frac{\partial U^1}{\partial d_{t,j}} + \frac{1}{\eta_t^2} \frac{\partial U^2}{\partial d_{t,j}}}{\frac{1}{\eta_t^m} \frac{\partial U^m}{\partial q_{t,j}^m}} \\
&\Rightarrow \gamma_{t,j}^m \left(\mu_t^m \frac{\partial U^m}{\partial q_{t,j}^m} \right) \geq \mu_t^1 \frac{\partial U^1}{\partial d_{t,j}} + \mu_t^2 \frac{\partial U^2}{\partial d_{t,j}}.
\end{aligned}$$

A.2 Implementation of Proposition 2

To operationalize the conditions in Proposition 2, we use binary variables $x_{t,s}^m \in \{0, 1\}$ to represent the preference relations R^m . Specifically $x_{t,s}^m = 1$ if $(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) R^m (\mathbf{q}_s^1, \mathbf{q}_s^2, \mathbf{d}_s)$ and $x_{t,s}^m = 0$ otherwise. Then, consistency with the conditions in Proposition 2 requires that there must exist a solution for the following programming problem (with C_t an arbitrary number that exceeds the total budget in observation t):

$$\mathbf{p}_t^{m,m'}(\mathbf{q}_t^m - \mathbf{q}_v^m) + \mathbf{p}_t^{m,l'}(\mathbf{q}_t^l - \mathbf{q}_v^l) + \mathbf{p}_t^{m,d'}(\mathbf{d}_t - \mathbf{d}_v) < x_{t,v}^M C_t; \quad (11)$$

$$x_{t,s}^M + x_{s,v}^M \leq 1 + x_{t,v}^M; \quad (12)$$

$$\mathbf{p}_v^{m,m'}(\mathbf{q}_v^m - \mathbf{q}_t^m) + \mathbf{p}_v^{m,l'}(\mathbf{q}_v^l - \mathbf{q}_t^l) + \mathbf{p}_v^{m,d'}(\mathbf{d}_v - \mathbf{d}_t) \leq (1 - x_{t,v}^M) C_v; \quad (13)$$

$$\forall j : p_{t,j}^{m,m} + p_{t,j}^{l,m} + \frac{\partial d_j}{\partial q_{t,j}^m} (p_{t,j}^{1,d} + p_{t,j}^{2,d}) = p_{t,j}; \quad (14)$$

$$\forall j : (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \leq \delta \left(p_{t,j}^{m,m} + \frac{\partial d_j}{\partial q_{t,j}^m} (p_{t,j}^{1,d} + p_{t,j}^{2,d}) \right); \quad (15)$$

$$\mathbf{p}_t^{m,l} \leq \pi(\mathbf{p}_t^{l,l} + \mathbf{p}_t^{m,l}). \quad (16)$$

Given information on private quantities \mathbf{q}^m and market prices \mathbf{p} , and conditional on (π, δ) , the conditions are linear in the unknowns $\mathbf{p}_t^{m,m}$, $\mathbf{p}_t^{m,l}$ and $\mathbf{p}_t^{m,d}$ and binary variables $x_{t,s}^m$. We solve this system of linear inequalities with binary variables using CPLEX.²³ Constraints (14)–(16) follow immediately from Proposition 2. Further, constraints (11)–(13) comply with the Generalized Axiom of Revealed Preference (GARP) for each individual m ($= 1$ or 2). Specifically, constraint (11) states that $\mathbf{p}_t^{m,m'}(\mathbf{q}_t^m - \mathbf{q}_v^m) + \mathbf{p}_t^{m,l'}(\mathbf{q}_t^l - \mathbf{q}_v^l) + \mathbf{p}_t^{m,d'}(\mathbf{d}_t - \mathbf{d}_v) \geq 0$ implies $x_{t,v}^m = 1$ (or $(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) R^m (\mathbf{q}_v^1, \mathbf{q}_v^2, \mathbf{d}_v)$). Next, constraint (12) imposes transitivity of the individual revealed preference relations R^m : if $x_{t,s}^m = 1$ (i.e. $(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) R^m (\mathbf{q}_s^1, \mathbf{q}_s^2, \mathbf{d}_s)$) and $x_{s,v}^m = 1$ (i.e. $(\mathbf{q}_s^1, \mathbf{q}_s^2, \mathbf{d}_s) R^m (\mathbf{q}_v^1, \mathbf{q}_v^2, \mathbf{d}_v)$) then $x_{t,v}^m = 1$ (i.e. $(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) R^m (\mathbf{q}_v^1, \mathbf{q}_v^2, \mathbf{d}_v)$). And constraint (13) requires $\mathbf{p}_v^{m,m'}(\mathbf{q}_v^m - \mathbf{q}_t^m) + \mathbf{p}_v^{m,l'}(\mathbf{q}_v^l - \mathbf{q}_t^l) + \mathbf{p}_v^{m,d'}(\mathbf{d}_v - \mathbf{d}_t) \leq 0$ if $x_{t,v}^m = 1$ (i.e. $(\mathbf{q}_t^1, \mathbf{q}_t^2, \mathbf{d}_t) R^m (\mathbf{q}_v^1, \mathbf{q}_v^2, \mathbf{d}_v)$).

B Independence

We illustrate the non-nestedness of the altruism and inequality aversion models by means of two examples. Example 1 provides a data set (with $T = 3$ and $n = 3$) that is consistent with a cooperative rationalization under 1–inequality aversion but not under π –altruism. Next, Example 2 contains a data set (with $T = 2$ and $n = 3$) that satisfies the rationalization conditions for 1–altruism but not for δ –inequality aversion. These examples demonstrate that not all data sets need to be simultaneously compatible with the altruism and inequality aversion models; the two models are empirically independent.

Example 1 The following price and quantity data are rationalizable under δ –inequality

²³See <https://www-01.ibm.com/software/commerce/optimization/cplex-optimizer/> for more details about the CPLEX software.

aversion but not under π -altruism (observations t in rows and goods j in columns)²⁴:

$$\mathbf{p} = \begin{bmatrix} 6 & 4 & 1 \\ 9 & 3 & 1 \\ 3 & 1 & 9 \end{bmatrix},$$

$$\mathbf{q}^1 = \begin{bmatrix} \frac{1}{6} & 2 & 0 \\ \frac{2}{3} & 0 & 0 \\ 0 & 0 & \frac{5}{3} \end{bmatrix}, \mathbf{q}^2 = \begin{bmatrix} \frac{1}{2} & 3 & 0 \\ 2 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

As a first step, the next three inequalities hold for this data set:

$$\begin{aligned} \mathbf{p}'_1 \mathbf{q}_1 &= 24 > \mathbf{p}'_1 (\mathbf{q}_2 + \mathbf{q}_3) = 18.67, \\ \mathbf{p}'_2 \mathbf{q}_2 &= 24 > \mathbf{p}'_2 (\mathbf{q}_1 + \mathbf{q}_3) = 23.67, \\ \mathbf{p}'_3 \mathbf{q}_3 &= 24 > \mathbf{p}'_3 (\mathbf{q}_1 + \mathbf{q}_2) = 15. \end{aligned}$$

Then, it follows from the general cooperative model without inequality aversion in Cherchye et al. (2007) that these data are inconsistent with cooperative rationalization for any value of π (i.e. the inconsistency result is independent of the restriction that is imposed on the degree of altruism).²⁵

However, the same data set is consistent with the inequality aversion model for $\delta = 1$. For example, this conclusion holds for the personalized prices (with $\alpha > 0$ sufficiently small)

$$\begin{aligned} \mathbf{p}^{1,1} &= \begin{bmatrix} 0 & 1 + \alpha & 1 \\ (6 + \frac{5}{6}) - \alpha & 3 & 1 \\ 3 & 1 & 11.7 + \alpha \end{bmatrix}, \mathbf{p}^{2,2} = \begin{bmatrix} 12 & 7 - \alpha & 1 \\ (11 + \frac{1}{6}) + \alpha & 3 & 1 \\ 3 & 1 & 6.3 - \alpha \end{bmatrix}, \\ \mathbf{p}^{1,d} &= \begin{bmatrix} 6 & 0 & 0 \\ (2 + \frac{1}{6}) + \alpha & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \mathbf{p}^{2,d} = \begin{bmatrix} 0 & 3 - \alpha & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 2.7 + \alpha \end{bmatrix}. \end{aligned}$$

Specifically, the shadow prices associated with own consumption exceed the corresponding market prices for individual 1 in observation 3 (good 3) and for individual 2 in observations 1 (goods 1 and 2) and 2 (good 1). One can then verify that these prices satisfy the rationalizability conditions when $\delta = 1$.

Example 2 The following price and quantity data are rationalizable under π -altruism but not under δ -inequality aversion.

$$\begin{aligned} \mathbf{p} &= \begin{bmatrix} 8 & 1 & 1 \\ 1 & 1 & 8 \end{bmatrix} \\ \mathbf{q}^1 &= \begin{bmatrix} 1.6 & 0 & 0.55 \\ 0.55 & 0 & 1.6 \end{bmatrix}; \mathbf{q}^2 = \begin{bmatrix} 1.3 & 0 & 0.25 \\ 0.25 & 0 & 1.3 \end{bmatrix} \end{aligned}$$

²⁴The use of zeroes in Example 1 and 2 is only for the ease of exposition.

²⁵In particular, the above three inequalities have a similar structure as the ones in Example 1 in Cherchye et al. (2007). These authors have shown that these three inequalities prevent a cooperative rationalization of any data set if negative consumption externalities are excluded.

We begin by showing that this data set is inconsistent with the inequality aversion model. As a first step, we infer conditions on shadow prices from the first-order conditions

$$p_{1,1}^{1,1} \geq 8, p_{1,3}^{1,1} \geq 1, p_{2,1}^{1,1} \geq 1, p_{2,3}^{1,1} \geq 8.$$

Rationality of individual 1 implies that either

$$\begin{aligned} \mathbf{p}_1^{1,1} \mathbf{q}_1^1 + \mathbf{p}_1^{1,d} \mathbf{d}_1 &< \mathbf{p}_1^{1,1} \mathbf{q}_2^1 + \mathbf{p}_1^{1,d} \mathbf{d}_2 \\ \Rightarrow \mathbf{p}_1^{1,1} (\mathbf{q}_1^1 - \mathbf{q}_2^1) + \mathbf{p}_1^{1,d} (\mathbf{d}_1 - \mathbf{d}_2) &< 0 \\ \Rightarrow 1.05 p_{1,1}^{1,1} - 1.05 p_{1,3}^{1,1} &< 0 \\ \Rightarrow p_{1,3}^{1,1} &> p_{1,1}^{1,1}. \end{aligned}$$

or – by similar reasoning – $p_{2,1}^{1,1} > p_{2,3}^{1,1}$. Hence, either $p_{1,1}^{1,1} < p_{1,3}^{1,1}$ or $p_{2,1}^{1,1} > p_{2,3}^{1,1}$. From the first-order conditions associated with inequality aversion, it follows that

$$\begin{aligned} 1 - p_{2,1}^{2,2} &= p_{2,1}^{1,1} - 1 \\ \Rightarrow p_{2,1}^{1,1} &= 2 - p_{2,1}^{2,2} \\ 1 - p_{1,3}^{2,2} &= p_{1,3}^{1,1} - 1 \\ \Rightarrow p_{1,3}^{1,1} &= 2 - p_{1,3}^{2,2}. \end{aligned}$$

However, $p_{1,3}^{1,1} = 2 - p_{1,3}^{2,2}$ (with $p_{1,3}^{2,2} \geq 0$) implies that $p_{1,3}^{1,1} > 8$ and hence $p_{1,3}^{1,1} > p_{1,1}^{1,1}$ is impossible. Analogously, $p_{2,1}^{1,1} = 2 - p_{2,1}^{2,2}$ (with $p_{2,1}^{2,2} \geq 0$) implies that $p_{2,1}^{1,1} > 8$ and, hence, $p_{2,1}^{1,1} > p_{2,3}^{1,1}$ is impossible. Given that both $p_{1,1}^{1,1} < p_{1,3}^{1,1}$ and $p_{2,1}^{1,1} > p_{2,3}^{1,1}$ are impossible, we conclude that the data set cannot be rationalized under δ -inequality aversion. Finally, the data set is compatible with π -altruism. For example, we can use the personalized prices (with $\alpha \in]7, 8]$)

$$\begin{aligned} \mathbf{p}^{1,1} &= \begin{bmatrix} 8 - \alpha & 0 & 1 \\ 1 & 0 & 8 \end{bmatrix}, \mathbf{p}^{2,2} = \begin{bmatrix} 8 & 0 & 1 \\ 1 & 0 & 8 - \alpha \end{bmatrix}, \\ \mathbf{p}^{1,2} &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & \alpha \end{bmatrix}, \mathbf{p}^{2,1} = \begin{bmatrix} \alpha & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}. \end{aligned}$$

It is easy to verify that these prices satisfy the rationalizability conditions under 1-altruism. Intuitively, individual 1 altruistically contributes to good 3 whereas individual 2 altruistically contributes to good 1.

C Experimental design

Before the experiment had started, each child was allowed to taste the grapes, mandarins and letter biscuits. They were instructed that these products were similar to the products they could choose in a next step. It was stated multiple times that each product was from the same brand and had the same quality.

Next, randomly assigned dyads of children were welcomed one at a time in a separate room. We explained that they had to choose 9 successive times but that they would only

receive one (randomly selected; see below) consumption bundle afterwards. Each dyad was presented with the first of nine choice sets. Each choice set was represented by seven plates containing combinations of grapes, mandarins and letter biscuits (shown in Table 9). The bundle on each plate corresponded to a specific point on an (implicit) budget hyperplane defined by a budget of 24 tokens and the prices (shown in Table 10) associated with the choice problem at hand. As a result, each consumption choice automatically satisfied the corresponding budget constraint (with equality).

The children were instructed to choose – jointly – one out of seven plates. The plates were physically present in the room. The dyad members chose one plate and were asked to divide the content of this plate among each other, thereby filling two new plates. Each decision problem was discussed out loud, the outcome of each situation (i.e. two new plates of grapes, mandarins and/or letter biscuits) withheld and noted by the instructor.

Subsequently, we presented the next choice set, while again stating that this second choice was as important as the first one, and that choices were independent of each other. This process was repeated nine times. At the end of the experiment, the children were invited to draw a card with a number from one to nine. They received the corresponding bundle and allocation (which they consumed immediately after the experiment had ended).

D Models with both altruism and inequality aversion: empirical results

For the sample of children of our experiment, Table 11 reports the pass rates and power estimates of general models of other-regarding preferences, which account for both altruism (π) and inequality aversion (δ). Obviously, the first row of Table 11 (with values ranging from 0.46 to 0.78) gives the results of the inequality aversion model in Table 6, whereas the first column (with values ranging from 0.46 to 1) gives the results of the altruism model in Table 6.

In general, the results in Table 11 confirm that allowing for altruism has a more favorable effect on the pass rates than allowing for inequality aversion. In fact, the pass rates of models that combine both sources of consumption externalities can also be interesting on their own. For example, under the restriction that both π and δ cannot exceed 0.3, we can rationalize the consumption behavior of 76 per cent of the dyads in our sample. By contrast, limited altruism (with $\pi \leq 0.3$) without inequality aversion (i.e. $\delta = 0$) can rationalize only 64% of the observed dyads' behavior, while limited inequality aversion (with $\delta \leq 0.3$) without altruism (i.e. $\pi = 0$) obtains a pass rate of no more than 60%.

On the other hand, combining different sources of externalities also reduces the discriminatory power. For instance, the pass rates are maximized (i.e. equal to one) when $\pi = 1$. Higher levels of inequality aversion cannot increase the pass rates. However, they may further reduce discriminatory power, so obtaining a model with less convincing empirical support.

Quantities			Quantities		
Grapes	Mandarins	Biscuits	Grapes	Mandarins	Biscuits
Choice 1			Choice 6		
3	0	0	4	1	2.66
0	6	0	6	1.5	0
0	0	24	0	1.5	4
1	2	8	6	0	4
1.5	0	12	Choice 6		
1.5	3	0	0	2.66	0
0	3	12	0	0	8
Choice 2			24	0	0
3	0	0	8	0.88	2.66
0	8	0	12	1.32	0
0	0	12	0	1.32	4
1	2.66	4	12	0	4
1.5	0	6	Choice 7		
1.5	4	0	0	0	3
0	4	6	6	0	0
Choice 3			0	24	0
2.66	0	0	2	8	1
0	8	0	0	12	1.5
0	0	24	3	0	1.5
0.88	2.66	8	3	12	0
1.32	0	12	Choice 8		
1.32	4	0	0	0	3
0	4	12	8	0	0
Choice 4			0	12	0
0	3	0	2.66	4	1
0	0	6	0	6	1.5
24	0	0	4	0	1.5
8	1	2	4	6	0
12	1.5	0	Choice 9		
0	1.5	3	0	0	2.66
12	0	3	8	0	0
Choice 5			0	24	0
0	3	0	2.66	8	0.88
0	0	8	0	12	1.32
12	0	0	4	0	1.32
			4	12	0

Table 9: The 9 discrete choices sets

Prices		
1 unit of grapes	1 unit of mandarins	1 unit of letter biscuits
8	4	1
8	3	2
9	3	1
1	8	4
2	8	3
1	9	3
4	1	8
3	2	8
3	1	9

Table 10: Prices

δ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.75	1
π									
0	0.46 (0.97)	0.52 (0.95)	0.58 (0.93)	0.6 (0.91)	0.62 (0.89)	0.68 (0.88)	0.72 (0.87)	0.78 (0.85)	0.78 (0.84)
0.1	0.52 (0.94)	0.56 (0.92)	0.64 (0.89)	0.64 (0.87)	0.7 (0.86)	0.78 (0.84)	0.8 (0.83)	0.84 (0.83)	0.86 (0.81)
0.2	0.58 (0.89)	0.62 (0.87)	0.66 (0.85)	0.7 (0.84)	0.78 (0.82)	0.8 (0.81)	0.82 (0.80)	0.86 (0.80)	0.86 (0.79)
0.3	0.64 (0.86)	0.70 (0.84)	0.7 (0.82)	0.76 (0.81)	0.78 (0.80)	0.82 (0.79)	0.86 (0.78)	0.86 (0.77)	0.88 (0.76)
0.4	0.7 (0.83)	0.70 (0.82)	0.76 (0.80)	0.8 (0.79)	0.82 (0.77)	0.86 (0.76)	0.88 (0.76)	0.88 (0.75)	0.88 (0.74)
0.5	0.74 (0.81)	0.78 (0.80)	0.82 (0.78)	0.82 (0.77)	0.84 (0.76)	0.86 (0.75)	0.88 (0.74)	0.9 (0.74)	0.94 (0.73)
0.6	0.9 (0.79)	0.9 (0.78)	0.9 (0.77)	0.92 (0.76)	0.94 (0.75)	0.96 (0.74)	0.96 (0.73)	0.96 (0.73)	0.96 (0.72)
0.75	0.94 (0.77)	0.96 (0.76)	0.96 (0.76)	0.96 (0.75)	0.96 (0.74)	0.96 (0.74)	0.96 (0.73)	0.96 (0.72)	1 (0.72)
1	1 (0.75)	1 (0.75)	1 (0.75)	1 (0.74)	1 (0.73)	1 (0.73)	1 (0.72)	1 (0.72)	1 (0.71)

Table 11: Pass rates (and discriminatory power) for cooperative rationalizations under π -altruism and δ -inequality aversion