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Is consumption efficiency within households falsifiable?

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Abstract The collective household model is based upon the assumption that decision makers have achieved efficient outcomes. This paradigm, which has become one of the leading approaches in family economics, is seldom, if ever, rejected, raising doubt about its falsifiability. We show that the standard approach to test the collective model may yield misleading inferences. We develop a new test procedure to assess its validity. Our approach extends to households that potentially include more than two decision makers. We provide an informal meta-analysis that suggests that much of the evidence in favor of collective rationality in the empirical literature appears to be inconsistent with our test. We illustrate the latter using data from a survey we have conducted in Burkina Faso. Consumption efficiency within monogamous households is not rejected using the standard testing procedure while it is clearly rejected using our proposed test procedure. Furthermore, our test also rejects consumption efficiency for bigamous households. We conclude that intra-household efficiency does yield empirically falsifiable restrictions despite being scarcely rejected in the literature.

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1 Introduction

The analysis of consumption decisions in multi-person households dates back to the pioneering work of (Becker 1973, 1974, 1981), which introduced the insight that individuals consume, not households. He was the first to show how marriage markets influence individual consumption within a marriage. He also proposed the Rotten Kid theorem, where an altruistic dictator made all the decisions on behalf of the household members, to explain how multi-person households could end-up behaving in a unitary way. These seminal papers lead to a burgeoning literature on individual consumption in marriage. For example, Grossbard (1976); Grossbard-Shechtman (1984) considered each member of the household as separate decision-makers whose interactions did not necessarily lead to an equilibrium allocation. Others assumed spouses allocated resources through a cooperative or non-cooperative bargaining game (e.g., Manser and Brown (1980); Lundberg and Pollak (1993).

More recently, the collective household model, which assumes that decision-makers achieve efficient outcomes, has become one of the main paradigms through which much of the research on consumption by multi-person households is conducted. One reason that explains its widespread use is that the model yields testable restrictions even though it rests upon a very small set of assumptions (Browning and Chiappori 1998; Chiappori and Ekeland 2006).

One particular set of falsifiable restrictions proposed in the literature to test efficiency focuses on the effects of so-called *distribution factors*.[1] There are three different ways distribution factors can be used to test the efficiency hypothesis. First, the *proportionality condition* states that the ratio of the marginal effect of two distribution factors must be equal across demand equations (Bourguignon et al. 1993; Browning et al. 1994; Bourguignon et al. 2009). Second, the *z-conditional demand condition* requires the effects of the remaining distribution factors to vanish once the demand equations are conditioned on the demand for some other good and upon substituting out one of the distribution factors (Bourguignon et al. 2009). Finally, the *rank condition* posits that the impact of the distribution factors must be at most of size one (Chiappori and Ekeland 2006).

The collective model is hardly ever rejected when using tests based on distribution factors, assuming given price levels. Some have thus been led to question the restrictive nature of the constraints imposed by the efficiency hypothesis. Others have raised concern over the statistical validity or power of the tests they imply. For instance, the *proportionality condition* implies a nonlinear restriction across equations which is generally tested by means of a Wald test (Bourguignon et al. 1993; Quisumbing and Maluccio 2003; Bobonis 2009). Yet, Wald tests are not invariant to algebraically equivalent nonlinear parameterization of the null hypothesis (Dagenais and Dufour 1991). Tests based on *z-conditional demands* are potentially more powerful because they boil down to testing single equation exclusion restrictions. Nevertheless, *z-conditional demand* equations include endogenous right-hand side variables and are typically estimated using an instrumental variables approach. The omitted distribution factors are natural instruments, but can prove to be weak.

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[1] Distribution factors are variables, such as the state of the marriage markets, that influence the decision process within the household but neither individual preferences nor the household budget set.

Finally, it is well-known that rank condition tests may suffer from poor statistical power in small samples (Camba-Mendeza and Kapetanios 2009).

Irrespective of the above issues, under-rejection of the efficiency hypothesis may arise for a more practical matter. In their seminal theoretical contribution, Bourguignon et al. (2009) (henceforth BBC2009) assume that *at least one distribution factor (locally) affects each demand equation.*[2] This assumption is however hardly ever satisfied empirically. To the best of our knowledge, among all the papers using either the *proportionality* or the *z-conditional demands* restriction to test the collective model, only two (Chiappori et al. 2002; Attanasio and Lechene 2014) satisfy the BBC2009 assumption. Thus, the vast majority neglects it. Yet, the standard testing approach used in the literature to investigate the efficiency hypothesis based on these restrictions requires the latter assumption to hold. Such inconsistency between the statistical procedures and their underlying assumptions, we argue, is a plausible candidate to explain under-rejection of the collective model.

However, the assumption of BBC2009 is perhaps too restrictive since distribution factors, by definition, need only affect two (or more) demand functions.[3] This is the starting point of our paper. We propose a falsifiable restriction of the efficiency hypothesis, which extends BBC2009's approach insofar as it does not require a distribution factor to (locally) affect each demand equation. The basic intuition is that, even under collective rationality, it is possible that the demands for a subset of goods (e.g., heating, electricity, lodging) may not be affected by the relative bargaining power of the household members, at least locally. In the case of two-member households, expenditures on these goods will then be independent from all distribution factors. On the other hand, the demands for those goods that are influenced by the spouses' bargaining power must depend on all distribution factors. This provides an alternative *all or nothing* testable restriction. We derive a set of testable conditions that takes this restriction into account and fully characterize collective rationality, absent price variations. In our approach, the *proportionality condition*, as well as the *z-conditional demand condition*, apply only to goods that depend on all the distribution factors.

As with *z-conditional demands*, the new falsifiable restriction boils down to testing an exclusion restriction in each single equation. Because it rests upon unconditional demand functions, endogeneity of right-hand side variables is not an issue for testing this constraint. Furthermore, contrary to the *proportionality* or the *z-conditional demands* restrictions, it does not require any of the distribution factors to be continuous. This is a great advantage since the most convincing distribution factors are random policy treatments. Finally, we show how our approach can be extended to households comprising potentially more than two decision makers.

To illustrate both our test procedure and how under-rejection of efficiency may arise, we use a field survey conducted by one of the co-authors of this paper to collect information on the decision process in very poor households from rural Burkina Faso. The social and customary environments in which these households evolve are

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[2] See the first sentence of their Proposition 2.

[3] A distribution factor cannot influence a single demand since, by definition, it cannot affect the household budget constraint.

likely to impede enforcement of efficient marriage contracts as these are deeply rooted in traditions that dictate expected behavior from both spouses. We investigate the efficiency of outcomes both in monogamous and bigamous households.[4]

The empirical analysis is based upon the widely used and flexible QUAIDS demand system. For both monogamous and bigamous households our data clearly reject the efficiency assumption using our test procedure. We also compute a test of Chiappori and Ekeland ([2006])'s *rank condition*. This latter is asymptotically equivalent to our (simpler) test procedure. Concern with sample size leads us to bootstrap the rank condition test using a recent procedure proposed by Portier and Delyon ([2014]). Results from this test are consistent with our own test as it rejects efficiency for both monogamous and bigamous households. We next test the *proportionality condition* despite the fact that the assumption of BBC2009 is not satisfied in our data, as is customarily done in the literature. Our results show that collective rationality is then (falsely) not rejected for monogamous households. We also show that the *z*-conditional demands approach cannot be implemented to test the efficiency of our Bukinabé households by lack of strong instruments, a problem we suspect is more common than what is usually reported.

Since the *all or nothing* restriction boils down to testing an exclusion restriction in each unconditional demand function, it is straightforward to review the empirical literature supporting collective rationality based on distribution factors.[5] Of the ten papers we reviewed, only four are consistent with collective rationality based on our test. Much of the evidence in favour of collective rationality is therefore open to criticism.

The rest of the paper is organized as follows. The next section presents our generalization of BBC2009's collective model to households comprising respectively two and potentially more decision-makers. We discuss our new procedure to test the model in each of these cases. We also illustrate how the standard approach to test BBC2009's model may yield misleading inference. Section 3 describes the socio-economic specificities of monogamous and polygamous households in Burkina Faso and discusses the choice of distribution factors. We also present the design of our survey and the main samples characteristics. Section 4 presents our estimation results and provides various tests of our generalized model for both monogamous and polygamous households. Section 5 concludes.

1.1 Theoretical restrictions of the collective model based on distribution factors

Our theoretical approach is based on the collective model in the absence of price variation as in BBC2009. We generalize their approach in two directions. First, we relax one of their crucial assumptions, namely that at least one distribution factor

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[4] In a somewhat complementary paper, Udry ([1996]) investigated *production* outcomes of rural Burkina Faso households and strongly rejected efficiency. Our analysis of household efficiency in consumption can be interpreted as conditional on the household production choices.

[5] Strictly speaking, testing the joint "all or nothing" hypothesis would require knowledge of the covariance between different parameter estimates. Since we do not have this information, and since we do dot compare the studies between themselves, we will refer to our discussion as an *informal* meta-analysis.

(locally) influences all the demand functions. Second, given that part of our empirical analysis focuses on bigamous households, we allow households to comprise more than two adult members.[6]

Consider a household with $I + 1$ members. Each member i draws his/her well-being from the consumption of N market commodities, which we represent by the vector $\mathbf{x}$. Each commodity may be consumed privately or publicly by household members. All prices are normalized to 1 so that the household budget corresponds to $\boldsymbol{\iota}'\mathbf{x} = m$, where $\boldsymbol{\iota}$ is a unit vector of dimension N and m is the level of exogenous household expenditures.[7]

Each member i has his own preferences $U^i(\mathbf{x})$ over (private and public) goods consumed in the household. No restrictions are imposed on the nature of the preferences. They can be egotistic or altruistic and may involve externalities or other types of preference interactions.[8] We assume that $U^i(\mathbf{x})$ is strongly concave, twice differentiable in $\mathbf{x}$ and increasing in each of its arguments.

Under rationality, the outcomes of the household decision process are assumed to be Pareto-efficient. This means that the household chooses a vector $\mathbf{x}$ such that no other feasible vector could make all members at least as well off and at least one member strictly better off. The collective model also allows the possibility for exogenous variables, called *distribution factors*, to influence the household's decisions. These variables are denoted by the vector $\mathbf{z}$ of dimension K.

The influence of these factors can be understood within a bargaining framework where each member has an outside option. The poorer his/her outside options, the more he/she will be willing to compromise and thus the lower will be his/her bargaining power. As a result, the less the consumption decisions will correspond to his/her preferences.

Outside options can vary across individuals and cultures. For example, members could behave non-cooperatively in case of minor disagreements (Lundberg and Pollak 1993; Chen and Woolley 2001) and eventually separate in case of major disagreements (Manser and Brown 1980; McElroy 1990). In the latter case, the state of the marriage market as proxied by the sex ratio (Chiappori et al. 2002), the nature of divorce laws (Gray 1998; Chiappori et al. 2002) and the relative contribution of the spouse to the household income (Browning and Chiappori 1998; Dauphin et al. 2011) have been considered as distribution factors in the literature. In the context of developing countries, Haddad and Kanbur (1992) stress the possibility for women to return to their native families in case of disagreement, and discrimination against women in the market place as potential distribution factors.

The setting of collective rationality is equivalent to stating that there exists a vector $\boldsymbol{\mu}(m, \mathbf{z})$ of I non-negative *Pareto weights* such that $\mathbf{x}$ is the solution to the

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[6] Note that Dauphin et al. (2011) investigate the efficiency of households comprising three potential decision-makers (couples with an adult child) using price-based statistical tests.

[7] This assumes that the household does not produce any of these N goods, or that the goods produced within the household can be freely sold and purchased on the market.

[8] This notation is used to simplify the presentation. Note that if a good is purely private to member i, then the marginal utility of the other members for that good will simply be zero.

following program:

$$\text{Max}\, \mu(m, \mathbf{z})' \big[U^1(\mathbf{x}), \ldots, U^I(\mathbf{x}) \big] + U^{I+1}(\mathbf{x})$$
$$\text{subject to } \iota' \mathbf{x} = m.$$

Thus the household *pseudo-utility function* to be maximized is a weighted sum of the individual utility functions. The Pareto weight associated with the preferences of member i (for $i \neq I + 1$) can be interpreted as the importance attached to these, relative to those of the $(I + 1)^{th}$ member, in the household decision process. If the Pareto weight of a given member is equal to zero, the household does not take into account that member's preferences in the decision process, other than via the possible caring preferences of the other members. The I Pareto weights can therefore be viewed as the distribution of decision power within the household and the number of decision-makers as the number of strictly positive Pareto weights plus one.

The Pareto weights might be functions of distribution factors and of household expenditures, in which case they are assumed to be twice continuously differentiable in $(m, \mathbf{z})$. It should be noted that some weights may be (locally) constant while others may respond to distribution factors. Furthermore, the non-constant weights may not all (locally) respond to the same distribution factors. When all the weights are constants, the household is said to behave rationally in a unitary way because the objective function can be interpreted as representing a unique utility function. When some of the weights are non-constants, the household is said to behave rationally in a collective way because the objective function cannot be interpreted as representing a unique set of preferences.

The demand system obtained from solving the above program for $\mathbf{x}$ can be written as: $\mathbf{x} = \hat{\mathbf{x}}(m, \mu(m, \mathbf{z}))$, with $\iota' \hat{\mathbf{x}}(m, \mu(m, \mathbf{z})) = m$ from the adding-up restriction. This shows that the distribution factors influence household consumption choices only through the non-constant Pareto weights. This follows from the fact that the distribution factors do not affect the Paretian frontier of the household consumption possibilities, but only the household's location on it. Clearly, since the Pareto weights are unobservable so is the structural demand system. Yet, it is still possible to test whether the reduced form of the latter, $\mathbf{x}(m, \mathbf{z})$, satisfies:

$$\mathbf{x}(m, \mathbf{z}) \equiv \hat{\mathbf{x}}(m, \mu(m, \mathbf{z})). \tag{1}$$

Proposition 2 of BBC2009 assumes that at least one distribution factor (locally) affects each demand function. Yet, distribution factors need not locally influence more than two of the latter to yield falsifiable restrictions. We thus start by relaxing this assumption and derive the appropriate test procedure. Next, we generalize the test to the case where a household comprises more than two potential decision-makers.

1.2 Generalization of proposition 2 of BBC2009 - two decison-makers

Consider a partition $\mathbf{x} \equiv [\mathbf{x}'_J, \mathbf{x}_{-J'}]'$ of the demand system and a partition $\mathbf{z} \equiv [\mathbf{z}'_J, \mathbf{z}_{-J'}]'$ of the set of distribution factors, with $\mathbf{x}_J$ and $\mathbf{z}_J$ having the same dimension J.

Given such a partition, (1) can be written as:[9]

$$\mathbf{x}_J = \mathbf{x}_J(\mathbf{z}_J, \mathbf{z}_{-J}) \equiv \hat{\mathbf{x}}_J(\mu(\mathbf{z}_J, \mathbf{z}_{-J})), \tag{2}$$

$$\mathbf{x}_{-J} = \mathbf{x}_{-J}(\mathbf{z}_J, \mathbf{z}_{-J}) \equiv \hat{\mathbf{x}}_{-J}(\mu(\mathbf{z}_J, \mathbf{z}_{-J})). \tag{3}$$

If the sub-system of reduced-form demand functions in (2) has continuous first partial derivatives and is such that $D_{\mathbf{z}_J}\mathbf{x}_J(\mathbf{z}_J, \mathbf{z}_{-J})$ is non-singular at a point $P = (\mathbf{z}_j, \mathbf{z}_{-j})$, then we can use the *Implicit Function Theorem* to invert $\mathbf{x}_j$ and $\mathbf{z}_j$ in some open neighborhood of P to get the following local inverse function:

$$\mathbf{z}_J = \mathbf{z}_J(\mathbf{x}_J, \mathbf{z}_{-J}),$$

which has continuous first partial derivatives. Upon substituting the latter into (2) and (3) we get:

$$\mathbf{x}_J = \overline{\mathbf{x}}_J(\mathbf{x}_J, \mathbf{z}_{-J}) \equiv \mathbf{x}_J(\mathbf{z}_J(\mathbf{x}_J, \mathbf{z}_{-J}), \mathbf{z}_{-J}) \equiv \hat{\mathbf{x}}_J(\mu(\mathbf{z}_J(\mathbf{x}_J, \mathbf{z}_{-J}), \mathbf{z}_{-J})), \tag{4}$$

$$\mathbf{x}_{-J} = \overline{\mathbf{x}}_{-J}(\mathbf{x}_J, \mathbf{z}_{-J}) \equiv \mathbf{x}_{-J}(\mathbf{z}_J(\mathbf{x}_J, \mathbf{z}_{-J}), \mathbf{z}_{-J}) \equiv \hat{\mathbf{x}}_{-J}(\mu(\mathbf{z}_J(\mathbf{x}_J, \mathbf{z}_{-J}), \mathbf{z}_{-J})). \tag{5}$$

The (local) sub-system of demands $\mathbf{x}_{-J}$ in (5) is written as a function of the sub-system of (local) demands $\mathbf{x}_J$ and of the distribution factors $\mathbf{z}_{-J}$. These are the so-called *z-conditional demands* proposed by BBC2009. The sub-system $\mathbf{x}_{-J}$ is said to be $\mathbf{z}_J$-conditional, since it is conditional on the inversion of $\mathbf{z}_J$. We further assume that $\mu(\mathbf{z})$ and $\hat{\mathbf{x}}(\mu(\mathbf{z}))$ are differentiable at the point P. The first generalization is as follows:

Proposition 1 *A system of $N \geq 2$ demand functions of a household with $I + 1 = 2$ members is locally compatible with rationality if, and only if, distribution factors, $\mathbf{z}$, either do not influence the demand system (unitary rationality):*

$$D_{\mathbf{z}}x_n(\mathbf{z}) = 0 \quad \forall n = 1, \ldots, N, \tag{7a}$$

or influence it in the following way when $K \geq 2$ (collective rationality):[10]

$$D_{\mathbf{z}}x_n(\mathbf{z}) = 0 \, or \, D_{\mathbf{z}}x_n(\mathbf{z}) \neq \mathbf{0} \quad \forall n = 1, \ldots, N. \tag{7b}$$

Moreover, the demands for which $D_{\mathbf{z}}x_n(\mathbf{z}) \neq \mathbf{0}$, denoted $x_m^*(\mathbf{z})$ also satisfy:

$$\frac{\partial x_m^*(\mathbf{z})/\partial z_1}{\partial x_m^*(\mathbf{z})/\partial z_k} = \frac{\partial x_1^*(\mathbf{z})/\partial z_1}{\partial x_1^*(\mathbf{z})/\partial z_k} \neq 0 \quad \forall k = 2, \ldots, K, m = 2, \ldots, M \tag{7c}$$

and, equivalently,

$$D_{\mathbf{z}_{-1}}\overline{x}_m^*(x_1^*, \mathbf{z}_{-1}) = 0 \quad \forall m = 2, \ldots, M, \tag{7d}$$

where $2 \leq M \leq N$.

The proof is available in a web Appendix.[11] The proposition states that the demand system of a two-person household is compatible with rationality *if and only if* it either complies with unitary rationality, (7a), or with collective rationality, (7b), (7c), and, equivalently to the latter, (7d). According to Restriction (7a), a demand

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[9] Henceforth, we will omit m from the argument to simplify the notation.

[10] When $N \leq 2$ or $K = 1$, collective rationality imposes no restrictions on the demand system.

[11] https://www.ecn.ulaval.ca/guy_lacroix/Web_Appendix.pdf

system is compatible with *unitary rationality* if and only if none of its demand functions is influenced by distribution factors. Our new *all or nothing* Restriction (7b) stresses that a demand system that responds to at least two distribution factors is compatible with collective rationality if each of its demands either does not respond to any of the distribution factors or responds to all of the distribution factors. Equation (7c) further restricts the manner in which the distribution factors impact the demand functions that respond to all of the distribution factors (denoted x_m^*): the ratio of the marginal effects of any two distribution factors must be equal across the latter. Finally, Restriction (7d) is equivalent to (7c). It states that the demand functions x_m^* are compatible with collective rationality only if they no longer respond to the distribution factors once they are conditioned on any of them, i.e., are transformed into their z_1-conditional form. Many empirical applications investigate the efficiency hypothesis using (7c). In most cases, the tests ignore Restriction (7b). Yet, the two go hand-in-hand. We will argue later on that focusing on (7c) while ignoring (7b) partly explains why the efficiency assumption is hardly ever rejected.

The intuition behind Proposition 1 is the following. In a rational household composed of two members there is only one Pareto weight. The distribution factors, if they exist, can only exert their effect on consumption choices through this weight. If unitary rationality holds, then the Pareto weight is constant. Each of its demand, x_n, must therefore satisfy (7a). On the other hand, if collective rationality holds and distribution factors do exist, then the single Pareto weight must respond to all of them. If a given demand function, x_n, say, does not locally respond to the Pareto weight, it will respond to none of the distribution factors ($D_{\mathbf{z}} x_n(\mathbf{z}) = 0$). Conversely, if x_n does respond to the Pareto weight, it will be sensitive to all the distribution factors ($D_{\mathbf{z}} x_n(\mathbf{z}) \neq 0$). Each demand x_n stemming from a collectively rational household must therefore satisfy the all or nothing Restriction (7b). Furthermore, since distribution factors exert their effects through a single weight, the demand functions that respond to it, x_m^*, must be such that the ratio of the marginal effect of any two distribution factors is equal to the ratio of the marginal effect of the two distribution factors on the weight, and this ratio must be different from zero. Therefore, the ratio of the marginal effect of any two distribution factors is equal across x_m^* demands as stated by (7c). Finally, conditioning a given demand function, x_m^*, by another, x_1^* say, is equivalent to maintaining x_1^* constant. In order to maintain x_1^* constant, z_1 must compensate for the variations in $\mathbf{z}_{-1}$ in such a way that the variations in the weight cancel out. Restriction (7d) must thus hold for this z_1-conditional demand.

An important corollary to the all or nothing restriction is that a system in which some demands respond to a subset of distribution factors while other demands respond to another subset of distribution factors is not compatible with collective rationality when $I + 1 = 2$. The all or nothing restriction is absent from Proposition 2 of BBC2009 because it is assumed at the outset that one of the distribution factors (locally) affects all the demand functions. Since there is a single Pareto weight, this amounts to assuming that all the demand functions respond to the weight and therefore that they all respond to all the distribution factors affecting the weight. This is equivalent to assuming that all the demand functions satisfy (7b), and more precisely its second part, that is $D_{\mathbf{z}} x_n(\mathbf{z}) \neq 0$. Hence, in the BBC2009 framework our Proposition 1 boils down to Restriction (7c) and, equivalently to the latter, (7d).

Contrary to the *proportionality* and the *z-conditional demands* restrictions, the *all or nothing* condition does not in fact require any of the distribution factors to be continuous. This is a great advantage since the most convincing distribution factors are random policy treatments. The *all or nothing* and the *z-conditional demands* restrictions boils down to testing an exclusion restriction in each single equation. This type of restriction is likely to be more powerful than the *proportionality* restriction since we can use single-equation estimation methods and since single-exclusion tests are more robust than tests of equality of parameters across equations. Furthermore, because the *all or nothing* restriction rests upon unconditional demand functions, endogeneity of right-hand side variables is not an issue for testing this constraint. It thus appears that restriction (7b) is likely to be more powerful to reject collective rationality than restrictions (7c) and (7d).

1.3 Generalization of proposition 2 of BBC2009—multiple decision makers

Proposition 1 is valid for households in which it can legitimately be assumed that there are at most two decision-makers. Many household configurations (extended families, adult children, polygamous households, etc.), though, may potentially have more than two decision-makers.[12] It is relatively straightforward to extend Proposition 1 to multiple potential decision maker households.

Proposition 2 *A system of $N \geqslant I + 1$ demand functions of a household with $I + 1$ members is locally compatible with* **rationality** *if, and only if, the distribution factors z either do not influence the demand system (**unitary rationality**):*

$$D_{\mathbf{z}} x_n(\mathbf{z}) = 0 \quad \forall n = 1, \dots, N. \tag{8a}$$

*or influence it in the following way when $K \geq I + 1$ (**collective rationality**): there exists a non-negative $J \leq I - 1$ for which*[13]

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\begin{aligned}
&D_{\mathbf{z}_{-J}} \bar{x}_n(\mathbf{x}_J, \mathbf{z}_{-J}) = 0 \, or \\
&D_{\mathbf{z}_L^*} \bar{x}_n(\mathbf{x}_J, \mathbf{z}_{-J}) \neq \neq 0 \, and \, D_{\mathbf{z}_{-L}^*} \bar{x}_n(\mathbf{x}_J, \mathbf{z}_{-J}) = 0 \quad n = J+1, \dots, N,
\end{aligned}
\tag{8b}
$$

where $\mathbf{z}_{-J} \equiv \left[\mathbf{z}_L^{*'}, \mathbf{z}_{-L}^{*'} \right]'$ with $1 \leq L \leq K - J$. Moreover, when $2 \leq L$, the demand functions that satisfy $D_{\mathbf{z}_L^*} \bar{x} : n(\mathbf{x}_J, \mathbf{z}_{-J}) \neq \neq 0$, denoted $\bar{x}_m^*(\mathbf{x}_J, \mathbf{z}_{-J})$, must also satisfy:

$$\frac{\partial \bar{x}_m^*(\mathbf{x}_J, \mathbf{z}_{-J}) / \partial z_1^*}{\partial \bar{x}_m^*(\mathbf{x}_J, \mathbf{z}_{-J}) / \partial z_l^*} = \frac{\partial \bar{x}_1^*(\mathbf{x}_J, \mathbf{z}_{-J}) / \partial z_1^*}{\partial \bar{x}_1^*(\mathbf{x}_J, \mathbf{z}_{-J}) / \partial z_l^*} \neq 0 \quad \forall l = 2, \dots, L \quad m = 2, \dots, M \tag{8c}$$

and, equivalently,

$$D_{\mathbf{z}_{-(J+1)}} \bar{x}_m^*(\mathbf{x}_J, x_1^*, \mathbf{z}_{-(J+1)}) = 0 \quad \forall m = 2, \dots, M, \tag{8d}$$

where $2 \leq M \leq N - J$.

The proof is provided in a Web Appendix.[14] This proposition states that the demand system of an $I + 1$-person household is compatible with rationality if and

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[12] An earlier extension of *Proposition 2.ii* of BBC2009 to multiple decision makers can also be found in Dauphin and Fortin (2001).

[13] When $N \leq I + 1$ or $K < I + 1$, collective rationality imposes no restrictions on the demand.

[14] See https://www.ecn.ulaval.ca/guy_lacroix/Web_Appendix.pdf

only if it either complies with unitary rationality (8a) or with collective rationality (8b), (8c), and, equivalently to the latter, (8d). Restriction (8a) is identical to Restriction (7a). Restrictions (8b) and (8c) are equivalent to (7b) and (7c) but they involve z-conditional rather than unconditional demand functions. Restriction (8b) states that the demand system of an $I + 1$-person household influenced by at least $I + 1$ distribution factors is compatible with collective rationality if there is a non negative $J \leq I - 1$ for which each demand contained in $\mathbf{x}_{-J}$, once conditioned on $\mathbf{x}_J$, either does not respond to any of the remaining distribution factors ($\mathbf{z}_{-J}$) or responds to a subset of them, denoted $\mathbf{z}_L^*$.[15] This subset must be the same for all the $\mathbf{z}_J$-conditional demand functions. In other words, those $\mathbf{z}_J$-conditional demands that still respond to distribution factors must respond to the same subset of them. The latter may include all the remaining distribution factors or a subset of them. Hence, having some $\mathbf{z}_J$-conditional demand functions responding to some distribution factors and other $\mathbf{z}_J$-conditional demand functions responding to other distribution factors is incompatible with collective rationality. Restriction (8c) further states that the $\mathbf{z}_J$-conditional demand functions $(\bar{x} : m^*(\mathbf{x}_J, \mathbf{z}_{-J}))$ responding to distribution factors $\mathbf{z}_L^*$ are compatible with collective rationality only if the ratios of the marginal effect of any two distribution factors included in $\mathbf{z}_L^*$ are equal across them. Finally, and equivalently to Restriction (8c), Restriction (8d) stresses that the $\bar{x} : m^*(\mathbf{x}_J, \mathbf{z}_{-J})$ demand functions are compatible with collective rationality only if they no longer respond to the distribution factors once they are conditioned on one more demand influenced by $\mathbf{z}_L^*$ (say x_1^*).

Chiappori and Ekeland (2006) (henceforth CE2006) provide another generalization of Proposition 2 of BBC2009, which we present here in a slightly modified manner.

Proposition 3 *(Chiappori and Ekeland 2006) A system of $N \geqslant I + 1$ demand functions of a household with $I + 1$ decision-makers is compatible with **rationality** if, and only if, distribution factors, $\mathbf{z}$, either do not influence the demand system (**unitary rationality**):*

$$rank[D_{\mathbf{z}}\mathbf{x}(\mathbf{z})] = 0 \qquad (9a)$$

*or satisfies the following condition whenever $K \geqslant I + 1$ (**collective rationality**):*

$$0 < rank[D_{\mathbf{z}}\mathbf{x}(\mathbf{z})] \leq I. \qquad (9b)$$

See CE2006 for the proof. Restriction (9a) is identical to our restrictions (7a) and (8a). Restriction (9b) states that if there exists $K \geqslant I + 1$ distribution factors, then the rank of the matrix $D_{\mathbf{z}}\mathbf{x}(\mathbf{z})$ must be greater than zero, but no greater than I. Intuitively, there can be no more than I Pareto weights under collective rationality. Since the distribution factors only impact the demand system through the latter, if there are fewer weights than there are distribution factors, their effects on the demand functions must necessarily be linearly dependent. Propositions 2 and 3 are equivalent. If a demand system satisfies (8b), (8c) and (8d), it will also satisfy (9b) and vice versa. However, if (8b) is satisfied, but restrictions (8c) and (8d) do not apply because $L < 2$, then (9b) may not be satisfied. This is because (8b) is only necessary. However,

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[15] In the case where each Pareto weight depends on all distribution factors, one has $\mathbf{z}_L^* = \mathbf{z}_{-J}$.

under collective rationality, and as long as $K + 1 \geq I$, it will always be possible to partition $\mathbf{x} \equiv [\mathbf{x}'_J, \mathbf{x}_{-J'}]'$ and $\mathbf{z} \equiv [\mathbf{z}'_J, \mathbf{z}_{-J'}]'$ in such a way that $L \geq 2$.[16]

The two propositions provide falsifiable restrictions for an overall test of rationality. In the case of Proposition 2, the first step is to test whether all the demands satisfy Restriction (8a), i.e., to test whether households behave rationality in a unitary way. If this hypothesis is rejected, the next step is to test collective rationality. The general formulation of the null hypothesis corresponding to collective rationality is $H_0: J \leq I - 1$ vs. $H_1: J > I - 1$. Since H_0 is a composite hypothesis, a sequential approach can be followed. One should thus start by testing whether all the demand functions satisfy Restriction (8b) when $J = 0$. If this hypothesis is rejected, the Restriction (8b) has to be tested for $J = 1$ and so on until it is not rejected for $J \leq I - 1$. If the Restriction (8b) is not rejected for $J \leq I - 1$, the Restriction (8c) or (8b) should be tested for those demand functions that are influenced by distribution factors. If the latter hypothesis is not rejected, then testing stops and collective rationality is not rejected. Conversely, if Restriction (8c) or (8d) is rejected, then Restriction (8b) should be tested again for a higher J. If the restrictions (8b) and (8c) or (8d) are successively rejected for all $J \leq I - 1$, then collective rationality as well as overall rationality must be rejected. The same sequential approach must be used with Proposition 3. The first step is to test whether the rank of $D_{\mathbf{z}}\mathbf{x}(\mathbf{z})$ is equal to zero. If not so, then the next step is to test whether it is equal to 1 and so on until I is reached. If the rank is not found to be equal or inferior to I, then overall rationality is rejected. If the rank is found to be of any value greater than 1 but inferior or equal to I, then testing stops and collective rationality is not rejected.

1.4 Empirical investigations of household collective rationality

Household collective rationality is the object of much research in the empirical literature. In what follows, we present a brief and informal meta-analysis that illustrates how our propositions may partly explain why the standard testing approach is likely to under-reject the collective model based upon distribution factors.

Most papers focus on households composed of two adults, which is the concern of our Proposition 1. Demand systems are estimated using data from developed as well as developing countries and are based on a variety of functional forms (AIDS, QUAIDS, etc.). Likewise, a rich set of distribution factors are used to proxy spouses' relative bargaining power (e.g., relative income, age and assets at marriage).

As shown earlier, for collective rationality of two-person households to be satisfied, the all or nothing Restriction (7b) needs to hold and Restriction (7c) and, equivalently (7d), only applies to the subset of demand functions that are responding to all the distribution factors. Yet, it is customary in the literature to neglect Restriction (7b) and to test collective rationality by means of Restriction (7c), or Restriction (7d), over the full set of demands, thus including those that do not respond to distribution factors as well as those who respond to a subset of them. This, we argue, partly explains why collective rationality is likely to be under-

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[16] Note that just as for Proposition 2, Proposition 3 does not require any of the distribution factors to affect all the demands.

rejected. In short, the failure to reject the collective model may be an artifact of the testing procedure.

For illustration, we report in Table 1 a series of papers referred to in Chapter 5 of Browning et al. (2014) and in Naidoo (2015) whose empirical results are interpreted as generally supportive of the collective model. We see first in column 5 that among the ten papers using the proportionality condition or the z-conditional demands to test the collective model, only two of them (that is, Chiappori et al. 2002 and Attanasio and Lechene 2014) satisfy the BBC2009 assumption. Recall that this condition assumes that at least one distribution factor affects each demand equation. Second, among the ten papers, four of them (that is, Quisumbing and Maluccio 2003, Bayudan 2006, Bobonis 2009, Attanasio and Lechene 2014—columns 6 and 7) conclude that the collective model is not rejected though it is rejected, based on our all or nothing test. Note also that, according to our test, the unitary model is not rejected in Thomas et al. (1999) and Vermeulen (2005) as none of the distribution factors are statistically significant. This leaves only four papers which are consistent with collective rationality according to our test (Bourguignon et al. 1993; Thomas and Chen 1994; Browning and Chiappori 1998; Chiappori et al. 2002).[17]

For example, let us focus on the paper by Quisumbing and Maluccio (2003). It uses data from various developing countries to estimate household demand systems. Assets of spouses at marriage and spouses' schooling are treated as distribution factors. Results for Bangladesh show that the demand for food significantly responds only to the husband's assets, that the demand for education responds only to the wife's assets and the husband's schooling and that the demand for child clothing responds only to the husband's schooling. This is not compatible with collective rationality as it violates the all or nothing restriction. Indeed, in a demand equation where one distribution factor is statistically significant, all other distribution factors should also be significant. Results for Ethiopia show that food responds to the two assets distribution factors, but alcohol and tobacco only to the wife's assets. This is not compatible with collective rationality either. In both cases, Restriction (7c) is tested with a joint test over all demands and is not rejected, and hence nor is collective rationality.

The latter study is representative of how most papers test collective rationality. In what follows, we use data from rural Burkina Faso to investigate rationality within monogamous and bigamous households. All or nothing Restriction (7b) (monogamous) or (8b) (bigamous) is first tested. If satisfied, we next move on to test (7c) or (8c) as the case may be. We also test collective rationality using the asymptotically equivalent test of CE2006 rank condition. We next use the same approach as in the above papers and test Restriction (7c) irrespective of whether the all or nothing Restriction (7b) holds.

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[17] This analysis is based on *point hypothesis* testing, that is, on inspection of the marginal p-values of various estimates of $D_{\mathbf{z}}x_n(\mathbf{z}), \forall n = 1, \ldots, N$. Of course, as noted earlier, to . test the "all or nothing" *joint hypothesis* would require information on the covariance between the various coefficient estimates, which is unavailable. However, in papers where one distribution factor is random (e.g., generated from a randomized experiment), the covariance between the two distribution factors is likely to be close to zero.

Table 1 Papers testing the collective model on 2-person households with proportionality condition or z-conditional demands

Paper	Country	Goods	Distribution factors (DF)	BBC2009 assumption satisfied	Results of BBC2009 restrictions tests	Results of All or Nothing Restriction (7b) Test
Attanasio and Lechene (2014)	Mexico	Five types of food	Random assignment to Progresa (DF1); Family network size (DF2)	Yes	z-Conditional restriction not rejected for any of the demands. Strength of instruments for DF not reported.	**Rejected since one demand respond only to DF1.**
Bayudan (2006)	Philippines	Six different time uses	Probability of husband having the final say on wife's travel(DF1); Probability of wife autonomously deciding on hiring household help (DF2); Probability of husband deciding how wife's money should be spent (DF3)	**No since FD1 and FD2 affects significantly only one demand and FD3 affects significantly only two demands.**	Proportionality restriction not rejected based on joint test over all demands, but rejected for two cross tests.	**Rejected since one time-use only respond to DF2 and DF3, another time-use respond only to DF1 and a third one respond only to DF3.**
Bobonis (2009)	Mexico	Thirteen goods	Random assignment to Progresa (DF1); Deviation from average rainfall (DF2)	**No since DF1 affects only four demands and DF2 affects only seven demands.**	Proportionality restriction not rejected based on joint test over all demands. z-Conditional restriction not rejected based on joint test over all z-conditional demands, but rejected for five individual tests. Strength of instruments for DF not reported.	**Rejected since three demands are only affected by DF2.**
Bourguignon et al. (1993)	France	Nine commodities	Wife labor income; Husband labor income	**No since the two DF each affect only two demands.**	Proportionality restriction not rejected based on joint test over all demands.	Yes
Browning and Chiappori (1998)	Canada	Seven commodities	Wife's log earning; Difference in log earning of wife and husband	**No since the two DF each affect only two demands**	Proportionality restriction not rejected based on joint test over all demands.	Yes
Chiappori et al. (2002)	United-States	Labor supplies of wife and husband	Sex ratio; Divorce laws	Yes	Proportionality restriction not rejected based on joint test over all demands.	Yes
Quisumbing and Maluccio (2003)	Bangladesh, Indonesia, Ethiopia and South Africa	Five commodities	Assets of wife at marriage (DF1); Assets of husband at marriage (DF2); Wife's schooling (DF3); Husband's schooling (DF4)	**No for Bangladesh and Ethiopia since each FD affect two or less demands. No for Indonesia since none of the DF are individually significant. No for South Africa since only one significant DF in one demand.**	For the four countries, proportionality restriction not rejected based on joint test over all demands.	**Rejected for Bangladesh since one demand responds only to DF2, another demand responds only to DF1 and DF4 and a third one responds only to DF4. Rejected for Ethiopia since one demand responds only to FD1 and FD2 and another demand responds only to DF1. Not applicable for Indonesia since unitary model not rejected according to restriction 7a. Not applicable for South Africa since only one significant DF.**
Thomas et al. (1999) (not published)	Indonesia	Four child morbidities	Mother's assets at marriage; Father's assets at marriage	**No since none of the DF are individually significant.**	Proportionality restriction not rejected based on joint test over all demands.	**Not applicable since unitary model not rejected according to restriction 7a.**
Thomas and Chen (1994) (not published)	Taiwan	Ten commodities	Income of women; Income of men	**No since each FD affect only five demands** (Table 3).	Proportionality restriction not rejected based on cross tests.	Yes
Vermeulen (2005)	Netherlands	Labor supplies of wife and husband	Age difference between husband and wife; Husband's share in non-labor income; Difference in log wages of husband and wife.	**No since none of the DFs are individually significant**	Proportionality restriction not rejected.	**Not applicable since unitary model not rejected according to restriction 7a.**

Bold characters indicate rejection of either the BBC2009 assumption or that of the All or Nothing restriction

2 The burkinabé family

Burkina Faso is one of poorest countries in the world. In 2014, the country ranked 181th out of 185 countries, with a life expectancy of 56.3 years, an adult literacy rate of 28.7% and a GDP per capita of 1 602 PPP US$ (UNDP 2014).Polygamy is quite prevalent. It is estimated that up to 22% of men and 42% of women are in a polygamous union (INSD 2010).

2.1 Distribution factors

According to the anthropological literature on Burkina Faso, spouses tend to behave non-cooperatively when a disagreement arises, at least initially. The husband "refuses to give cereals, money and gifts to his wife and will favor another wife. The wife, in return, will refuse to carry out her domestic and conjugal duties […] The wife may thus refuse to fetch water from the well for him, to heat it up for him, to wash his clothes and give him food that she has herself produced or bought".[18] The more financially independent the wife is, the greater will be her bargaining power. The wife's contribution to the household income could thus qualify as a distribution factor.

Over the years , the husband may gradually accumulate enough wealth to pay for the dowry of an additional wife. The husband's threat of a co-wife may thus become more and more credible over time, thereby gradually reducing the bargaining power of the first wife, *ceteris paribus*. The duration of the marriage should thus qualify as a distribution factor in monogamous households. In the case of polygamous households, the anthropological literature has also highlighted that a wife's bargaining power depends on the number of years since marriage and on her rank. The wives "must submit to an internal hierarchy conditioned by age and the length of the marriage: although negligible when less than a decade separates their birth or their union, it is perceptible beyond that. […] Furthermore, the first wife has authority on the other wives".[19] This suggests to use the duration of the first wife's marriage relative to the duration of the second's wife marriage.

Two important remarks are in order. First, choosing appropriate distribution factors is difficult in that they are required to only affect allocations, not preferences, which is difficult to test. Thus the wife's contribution to the household (labor) income can be considered as a distribution factor if we assume separability between leisure and consumption. We are not aware of any study that tests the collective model with distribution factors that does not make this assumption. We acknowledge that it is more problematic in the context of self-consumption as in the present case, but assuming non-separable preferences would greatly complicate the empirical strategy.

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[18] Rookhuizen (1986), p. 59, free translation.

[19] Lallemand (1977), p. 263, free translation.

Given that the main purpose of our empirical analysis is to illustrate the testing procedure and to show that under-rejection might occur when the BBC2009 assumption is overlooked, we follow standard practice and assume separability.[20] More importantly we do not account for household production and its effect on the virtual household income and consumption decisions. In addition, while our model assumes that the marriage status of the household is exogenous, the above discussion suggests that it could be endogenous as it may partly be determined by the relative bargaining power of the (first) wife. Indeed, the higher the bargaining power of the wife is, the more likely she will be able to impose her (presumed) preference for monogamy. This may be the source of a selection bias in our estimators as our econometric analysis is conditional on the household marriage contract. A natural approach would involve modeling the marital status of the household. This however would greatly complicate the analysis while being peripheral to the main point we wish to underline in this article. On the other hand, it must be acknowledged that such a selectivity problem applies to almost all the empirical literature on collective rationality since the formation and dissolution of households is itself endogenous.

2.2 The survey

With an aim at testing household efficiency in Burkina Faso, Anyck Dauphin, one of the co-authors of this paper, conducted a field survey between January and March 1999 under the auspices of the Centre canadien d'étude et de coopération internationale (CECI). The information on the income of the different spouses was collected indirectly. Since most households live off of agriculture, and since agricultural production survey are very complex, the survey focused on household expenditures which can be considered as a good indicator of their permanent income. For each spouse, data were collected on expenditures on food and non-food products, durable goods and self-consumption.

The survey was conducted in the Province of Passoré which has a population of approximately 322,000[21], primarily because the CECI had been involved in the region for a long time and had established close links with the local institutions. The province is divided into nine administrative regions. In order to minimize cost, the survey was limited to the five regions that were deemed the most representative of the economic and social fabric of the province. These include Dakiégré, Pelegtanga, Rallo, and Sectors 1 and 5 of the City of Yako (Yako-1, Yako-5).

To be included in the sample a household had to meet the following two conditions: (1) The (male) household head as well as his spouse(s) had to be less than 70 years of age and; (2) They all had to live permanently on the same compound. Prior to sampling, a census was conducted in each of the five regions to identify married households and to determine eligibility. Over 125 married households were then

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[20] Consequently, we implicitly ignore the whole area of the household decisions that concern time allocation, and in particular leisure choices. Note that the original formulation of the collective model did the exact opposite (see Apps and Rees 1988; Chiappori 1988): It focused on household labor supply but omitted the allocation of consumption goods, thanks to the Hicksian composite-good theorem. In that framework, wage rates were the main distribution factors.

[21] According to the National 2006 Census.

randomly selected among those eligible in each region, except for the village of Dakiégré where all 111 households were selected.Overall, as many as 551 households out of 611 were interviewed (response rate = 90%).

2.3 Sample characteristics

Sample size for monogamous and bigamous households are 392 and 117, respectively. The main characteristics of these samples are presented in Table 2, which is divided into three separate panels. The first shows that more than 30% of monogamous households are Muslim, a percentage that increases to 44% in bigamous households. Monogamous husbands are on average 42 years old, that is 7 years younger than polygamous males. Wives from monogamous households are on average 33 years old, somewhat in-between the age of first and second wives of bigamous households. Not surprisingly then, monogamous wives with an average of 3.5 children have fewer (more) children than the first (second) wife of bigamous households. The estimated budget for monogamous and bigamous households over a two month period covered by the survey are respectively 117 620 CFA and 216 743 CFA.

Table 2 Sample characteristics

	Monogamous households		Bigamous households	
	Mean	(Std error)	Mean	(Std error)
Muslim	32	–	44	–
Age Husband	42	(12.49)	49	(11.27)
Age Wife1	33	(11.84)	42	(11.07)
Age Wife2			31	(8.66)
Children Wife1	3.47	(2.33)	4.75	(2.36)
Children Wife2			3.16	(2.17)
Total Expenditures (CFA francs)	177 620	(111 803)	216 743	(100 045)
Budget Shares				
PC-Husband	0.0360	(0.0419)	0.0225	(0.0288)
PC-Wife1	0.0995	(0.0763)	0.0397	(0.0383)
PC-Wife2			0.0468	(0.0419)
PC-Child1	0.0534	(0.0462)	0.0313	(0.0285)
PC-Child2			0.0241	(0.0238)
Millet	0.0730	(0.1131)	0.1056	(0.1340)
Other Foods	0.4222	(0.1515)	0.4343	(0.1389)
Distribution factors				
Share Income Wife1	0.232	(0.157)	0.1680	(0.0895)
Share Income Wife2			0.1426	(0.0927)
Duration Marriage Wife1	14	(15.75)	22	(10.09)
Duration Marriage Wife2			11	(8.56)

PC personal care

The ability to assess the impact of distribution factors on expenditures is greatly enhanced if the survey focuses on assignable goods. These may be consumed by more than one household member but individual consumption is observed in the data. *A priori*, distribution factors that favour a particular household member should have a noticeable impact on his/her share of a given assignable good. The field survey was thus designed to collect information on the main assignable goods consumed by each member of the household. Survey pretesting indicated that clothing and hairdressing were the two most important items that could qualify as assignable goods in the rural Burkinabé context. Expenditures on these two goods were aggregated into a single category which we refer to as "Personal Care". Each spouse in the household was thus surveyed about the expenditures made on these goods for his/her own purpose, and for those of the other spouses and their children. The second panel of the table reports the average share of the household budget devoted to the clothing and hairdressing of the husband (*PC-Husband*), his wives (*PC-Wife1* and *PC-Wife2*) and their respective children (*PC-Child1* and *PC-Child2*). The shares of personal care accruing to the wives are larger than those of husbands and children in both monogamous and bigamous households. In monogamous households the wives' share amounts to 9.95% while it represents about 4% for both wives in bigamous households. The main staple food, millet, represents between 7.3 and 10.5% of the household budget, whereas the remaining food items (*O-Food*) account for slightly more than 40%.

The last panel of the table focuses on distribution factors. In our data, a monogamous wife contributes on average to approximately 23% of total household income. In bigamous households, the first and second wives' shares are 17 and 14%, respectively. Finally, monogamous households had lasted approximately 14 years and bigamous households had formed 22 years prior to our survey. The time lapse between first and second marriages is about 11 years.

3 Estimation results

Our estimation strategy is threefold. For both monogamous and bigamous households we estimate a QUAIDS demand system. Given the relatively small size of our samples, we thought this parametric model would be a good approximation to a full-fledged non-parametric one. We first test rationality with Proposition 1 for monogamous households and with Proposition 2 for bigamous households. Second, we use the test of the rank condition proposed by CE2006. Finally, we test collective rationality for monogamous households using the restrictions proposed by Bourguignon et al. (2009), irrespective of whether one of the distribution factors locally affects each demand of the system.

3.1 Monogamous households

The demand system is composed of six non-durable goods, of which three are assignable: *PC-Husband*, *PC-Wife*, *PC-Children*, *Millet*, *Other Foods* and expenditures on remaining nondurable goods. Only the first five demands are estimated due to the adding-up constraint. Individual shares are regressed against the log of total

expenditures on non-durable goods (ln*Exp*) and its square (ln*Exp2*). The two distribution factors are the log of the wife's share of household income (*SIncomeW*) and the duration of marriage (*DMar*). We also control for location, religion, age of spouses and the number of children under 16 years of age (x_n). The budget shares functions (for $n = 1,…,5$) are written as:

$$w_n = \mathbf{x}'_n \boldsymbol{\alpha_n} + \beta_n \ln Exp + \theta_n (\ln Exp)^2 + \delta_n SIncomeW + \gamma_n DMar + \varepsilon_n \quad (6)$$

To account for the possibility that total expenditures on non-durable goods are endogenous, we included the residuals of the auxiliary regressions of the log of total expenditures and its square on a set of instruments in the QUAIDS specification in (6) as control functions. The instruments used in the first stage equation were the log of total income, its square and the sum of the number of years of education of the husband and his wives. Since households in rural Burkina Faso have next to no savings and spend very little on durable goods, not surprisingly, these instruments were found to be very strong. Given that the residuals proved to be not significant, we did not reject the exogeneity of the total expenditures in any regression. Therefore Table 3 focuses on the OLS estimation results. Several parameter estimates are statistically significant. Ethnic groups and location appear to be important determinants of expenditure shares. Husbands' age is negatively related to both *PC-Husband* and *PC-Wife* but positively related to *Other Foods*. Likewise, the number of children has a negative impact on *PC-Husband* and *PC-Wife* but a positive one on *PC-Children*, as expected. The log of expenditures and its square are not individually significant for any share, but are jointly significant for *PC-Children*, *Millet* and *Other Foods*.

Interestingly, the wife's share of total income (*SIncomeW*) impacts negatively *PC-Husband* and positively *PC-Children*. These results are consistent with a larger share of income translating into a larger bargaining power. Notice also that *DMar* usually appears to be unfavorable to the wife presumably because the likelihood of the husband contracting a new marriage increases.

3.2 Rationality tests based on proposition 1

Proposition 1 provides restrictions that are gradually more restrictive. This allows us to adopt a sequential approach. The first step is to test unitary rationality (7a), which assumes away the existence of distribution factors. It is straightforward to test this restriction based on point hypotheses through simple *t*-tests.[22] According to Table 3, this restriction must be rejected since the two distribution factors we consider are statistically significant in various demand functions.

We thus move on to test collective rationality using Restriction (7b). This *all or nothing* restriction is a necessary condition requiring that each demand function either do not respond to any of the distribution factors or respond to all of the distribution factors. Again, simple *t* tests of significance can be used.[23] As shown in

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[22] An alternative approach would be to implement a joint hypothesis test. The latter would lead to the same decision rule as long as the covariance between the estimates of our two distribution factors is negligible. Otherwise, a more complex test must be implemented.

[23] As long as the covariance between the estimates of our two distribution factors can be neglected

Table 3 OLS estimation of the QUAIDS demand system monogamous households

Variables	PC-husband	PC-wife	PC-children	Millet	Other foods
Intercept	−0.133	−0.841	−0.421	−1.022**	−3.024
	(−0.188)	(−0.622)	(−0.598)	(−2.326)	(−0.392)
Dakiégré	0.178**	0.128	−0.148**	1.275***	−0.026
	(2.281)	(1.061)	(−2.422)	(6.901)	(−0.097)
Pelegtanga	0.173**	0.060	−0.032	−0.124	−1.069***
	(2.149)	(0.445)	(−0.434)	(−1.174)	(−4.205)
Rallo	0.0248	−0.178*	−0.009	−0.0935	−0.327
	(0.406)	(−1.712)	(−0.142)	(−0.986)	(−1.410)
Yako-1	−0.140**	−0.452***	−0.053	1.518***	−0.549*
	(−1.987)	(−3.484)	(−0.568)	(7.588)	(−1.826)
Muslim	0.056	0.056	−0.106**	0.149	0.384**
	(1.127)	(0.669)	(−2.324)	(1.540)	(2.265)
Age husband	−0.126***	−0.119**	0.001	−0.036	0.270**
	(−4.327)	(−2.112)	(0.020)	(−0.454)	(2.142)
Age wife1	−0.0654	0.104	−0.127	0.091	−0.388
	(−1.329)	(0.935)	(−1.501)	(0.497)	(−1.642)
Children	−0.263***	−0.415**	0.542***	−0.23	0.359
	(−3.136)	(−2.264)	(4.181)	(−0.860)	(0.818)
ln(Total expenditures)	0.338	1.712	0.668	1.897***	6.144
	(0.286)	(0.761)	(0.569)	(2.595)	(0.480)
ln(Total expenditures)^2	−0.0129	−0.071	−0.0208	−0.086***	−0.273
	(−0.261)	(−0.759)	(−0.424)	(−2.821)	(−0.515)

Table 3 continued

Variables	PC–husband	PC–wife	PC–children	Millet	Other foods
Distribution Factors					
Share income wife1	−0.634**	0.832	0.731***	−0.340	−0.226
	(−2.308)	(1.578)	(2.882)	(−0.513)	(−0.207)
Duration marriage wife1	0.105**	−0.241**	0.137	0.0147	0.307
	(2.366)	(−2.260)	(1.582)	(0.077)	(1.327)
Observations	392	392	392	392	392
R^2	0.287	0.295	0.158	0.425	0.158
$H_0: \beta_n = \theta_n = 0$ (Eq. 11)					
$F_{(2, 369)}$	0.24	0.29	6.34***	5.82***	3.65***
P-value	0.7866	0.7486	0.0020	0.0032	0.0268

t-statistics in parentheses

PC personal care.

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 3, the shares of *PC-Wife* and *PC-Children* respond significantly only to one out of two distribution factors. Therefore, collective rationality must be rejected.

3.3 Rationality tests based on CE2006

As stressed earlier, the CE2006 rank condition test is asymptotically equivalent to the test of our Proposition 1. Their test is carried out sequentially, starting with the Restriction (9a). The null hypothesis $H_0:rank[D_z\mathbf{x}(\mathbf{z})] = 0$ is computed using an F statistic to test that both distribution factors are simultaneously statistically significant in all the demand functions. The $F(10,1870)$ statistic is equal to 4.28 and has an associated P-value of 0.00001. Clearly, the unitary rationality is rejected. We thus move on and test $H_0:rank[D_z\mathbf{x}(\mathbf{z})] = 1$. Since our sample is relatively small, we implement a recent *constrained bootstrap method* proposed by Portier and Delyon (2014) to insure both our proposition and that of CE2006 have similar statistical properties.[24] More precisely, we use the test statistic proposed by Li (1991) and we estimate its bootstrap distribution under the null hypothesis that $rank[D_z\mathbf{x}(\mathbf{z})] = 1$ as suggested by Portier and Delyon (2014). The sampling value of the statistic is equal to 0.00577 and has a P-value of 0.0001. The CE2006 test is thus consistent with our own test in rejecting collective rationality.

3.4 Rationality tests based on BBC2009

Recall that Proposition 2 of BBC2009 requires that all the demands function respond to at least one common distribution factor. As stressed earlier, this condition is hardly ever satisfied. It is certainly not in our data. We nevertheless omit this condition and carry on testing collective rationality. Restriction *ii* of Proposition 2 of BBC2009 stipulates that for collective rationality to hold the ratio of the marginal effects of the two distribution factors must be equal across the demand functions, i.e., H_0: $\delta_1/\gamma_1 = \delta_2/\gamma_2 = \delta_3/\gamma_3 = \delta_4/\gamma_4 = \delta_5/\gamma_5$. Based on the parameter estimates of Table 4, we get a test statistic of $\chi^2(4) = 7.02$ with an associated P-value of 0.135. In other words, the null assumption can not be rejected and so neither is collective rationality.

Obviously, this test is fundamentally flawed because it is based on a false premise. Indeed, both distribution factors are not statistically different from zero in three demand functions. Hence, the ratios of the marginal effects are essentially zero in most cases. As a matter of fact, a joint test that all the ratios are equal to zero, i.e., H_0: $\delta_1/\gamma_1 = \delta_2/\gamma_2 = \delta_3/\gamma_3 = \delta_4/\gamma_4 = \delta_5/\gamma_5 = 0$, yields a test statistic of $\chi^2(5) = 9.06$ with an

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[24] Portier and Delyon (2014) developed a so-called *constrained bootstrap method* which allows to compute the bootstrap distribution of three distinct rank-test statistics proposed in the literature under the null hypothesis that the rank of the matrix is of a given size. Among the three available statistics, we have chosen that of Li (1991) since the consistency of its associated constrained bootstrap test relies on less stringent conditions than the other two. The Li (1991) statistics is the following: $\hat{\Lambda} = n \sum_{p=m+1}^{P} \hat{\lambda}_p$, where n is the sample size, $(\hat{\lambda}_1, \ldots, \hat{\lambda}_P)$ are the singular values of the matrix $D_z\mathbf{x}(\mathbf{z})$ arranged in descending order and $m > 0$ is the assumed rank of $D_z\mathbf{x}(\mathbf{z})$. The null assumption is $H_0 : rank[D_z\mathbf{x}(\mathbf{z})] = m$ against $H_1 : rank[D_z\mathbf{x}(\mathbf{z})] > m$. Since this procedure cannot test whether $H_0 : rank[D_z\mathbf{x}(\mathbf{z})] = 0$, we begin with an F test that all the distribution factors are simultaneously statistically significant in all the demand functions. If rejected, the next step is to test $H_0 : rank[D_z\mathbf{x}(\mathbf{z})] = 1$ with a constrained bootstrap test of $\hat{\Lambda}$, and so on until the maximum rank of $D_z\mathbf{x}(\mathbf{z})$ (i.e., *I*) is reached.

Table 4 OLS estimation of the demand system—bigamous households

Variables	PC-husband	PC-wife1	PC-wife2	PC-children1	PC-children2	Millet	O-foods
Intercept	-0.925	-1.779	-1.252	-0.991	-0.187	12.30	-3.001
	(-1.100)	(-1.205)	(-1.116)	(-0.826)	(-0.145)	(1.185)	(-0.332)
Diakégré	0.265***	0.123	0.203**	0.012	-0.001	-0.009	0.977*
	(3.261)	(1.032)	(2.163)	(0.155)	(-0.012)	(-0.019)	(1.912)
Pelegtanga	0.193**	0.026	0.338***	0.251**	0.127	-1.749***	0.452
	(2.134)	(0.204)	(2.846)	(2.439)	(1.381)	(-3.962)	(0.883)
Rallo	0.005	-0.057	0.0797	0.114	0.062	-0.012	0.293
	(0.066)	(-0.453)	(0.764)	(1.259)	(0.786)	(-0.027)	(0.529)
Yako-1	0.118	-0.145	-0.042	0.125	0.033	-0.972**	0.461
	(1.325)	(-0.982)	(-0.322)	(1.232)	(0.401)	(-2.104)	(0.634)
Muslim	0.037	0.119	0.200**	0.187**	0.153**	-0.746***	0.741**
	(0.466)	(1.319)	(2.060)	(2.383)	(2.143)	(-3.244)	(2.454)
Age husband	-0.010	-0.019	-0.047	-0.064	-0.076**	-0.193	0.127
	(-0.174)	(-0.313)	(-0.740)	(-1.559)	(-2.026)	(-1.179)	(0.609)
Age wife1	-0.046	-0.039	0.007	0.050	0.103**	0.077	-0.149
	(-0.835)	(-0.594)	(0.103)	(0.982)	(2.306)	(0.421)	(-0.557)
Age wife2	-0.081	-0.071	-0.144*	-0.070	-0.044	0.206	0.246
	(-1.629)	(-1.006)	(-1.814)	(-0.140)	(-1.138)	(1.055)	(0.679)
Children wife1	0.047	0.132	0.203	0.264*	0.079	0.808	-0.716
	(0.390)	(0.719)	(1.113)	(1.779)	(0.700)	(1.357)	(-1.004)
Children wife2	-0.060	-0.169	-0.126	0.040	0.167	-0.605	0.835
	(-0.481)	(-0.700)	(-0.563)	(0.253)	(1.037)	(-0.880)	(0.668)
ln(Total expenditures)	1.627	3.049	2.234	1.610	0.418	-19.19	4.729

Table 4 continued

Variables	PC-husband	PC-wife1	PC-wife2	PC-children1	PC-children2	Millet	O-foods
	(1.157)	(1.253)	(1.188)	(0.808)	(0.200)	(−1.140)	(0.320)
ln(Total expenditures)^2	−0.067	−0.123	−0.092	−0.064	−0.017	0.766	−0.182
	(−1.147)	(−1.225)	(−1.170)	(−0.775)	(−0.194)	(1.123)	(−0.302)
Distribution Factors							
Share income wife1	−1.034****	0.197	−1.158**	0.729*	−0.328	0.895	−0.702
	(−2.975)	(0.363)	(−2.200)	(1.740)	(−0.991)	(0.510)	(−0.293)
Share income wife2	−0.092	−0.215	1.867***	0.027	1.136***	−0.344	0.516
	(−0.242)	(−0.446)	(3.916)	(0.068)	(3.658)	(−0.228)	(0.247)
Share duration marriage wife1	−0.316	−0.378	−0.019	0.140	−0.675***	−1.664*	3.253**
	(−1.175)	(−0.970)	(−0.049)	(0.618)	(−3.085)	(−1.839)	(2.061)
Observations	117	117	117	117	117	117	117
R^2	0.432	0.257	0.387	0.223	0.367	0.494	0.175

t-statistics in parentheses

PC personal care

*** $p < .01$, ** $p < .05$, * $p < .1$.

associated *P*-value of 0.107. In other words, we can not reject the null assumption that all the ratios are equal to zero. A naive application of the BBC2009 test would thus lead us to (falsely) not to reject collective rationality.

The Proposition 2 of BBC2009 provides another restriction stated in terms of *z*-demand functions which is equivalent to the Restriction *ii*. This restriction, like our Restriction (7d), requires that a given demand function be inverted relative to one of its distribution factors and that the latter be substituted into the remaining demand functions. It states that the resulting *z*-conditional demand functions must no longer respond to the distribution factors. One difficulty with this approach is that the conditioning demand function must be instrumented to obtain consistent estimators. The literature suggests the substituted distribution factor be used as an instrument. We thus considered the four possibilities provided by Table 3, that is inverting *PC-Husband* or *PC-Children* on *SIncomeW* and inverting *PC-Husband* or *PC-Wife* on *DMar*. For each of these possibilities, we tested whether the distribution factor constituted an adequate instrument. In each case, the Cragg-Donald Wald *F* statistic, which is equal to the effective F statistic in the just-identified case, was found to be well below the three critical values suggested in the literature. These are the rule of thumb of Staiger and Stock (1997), the Stock and Yogo (2005) critical value for 10% maximal IV size distortion, and the critical value associated to a bias of Nagar of 10% as proposed by Montiel and Pflueger (2013). Furthermore, despite our best efforts, we could not come up with a single set of satisfactory instruments in an overidentified context. All proved to be weak. Consequently, we elected not to investigate Restriction *iii* of BBC2009 further.[25]

3.5 Bigamous households

The demand system includes the same items as with monogamous households but in addition includes personal care of the second wife (*PC-Wife2*) and her children (*PC-Children2*). The system is composed of eight non-durable goods, five of which are assignable. The first seven demand functions are estimated using the QUAIDS system. The three distribution factors include the log of the share of income of each wife relative to total household income as well as the share of the duration of the first wife's marriage relative to the total duration of the marriage of the two wives, *i.e.*, *SDMarW1*/The other explanatory variables are the same as with monogamous households but also include the age of the second wife as well as her number of children aged under 16. The budget shares (for $n = 1,\ldots,7$) are written as follows:

$$
\begin{aligned}
w_n = {} & \mathbf{x}'_n \alpha_{\boldsymbol{n}} + \beta_n \ln Exp + \theta_n (\ln Exp)^2 + \delta_n SIncomeW1 \\
& + \rho_n SIncomeW2 + \gamma_n SDMarW1 + \varepsilon_n
\end{aligned}
\tag{7}
$$

Table 4 reports the OLS estimation results. Several parameter estimates are statistically significant. As with monogamous households, ethnic origin and region of residence are important determinants of spending patterns. The log of total expenditures and its square are not statistically significant.

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[25] Few, if any, papers ever report tests of weak instruments in the empirical literature. For instance, no paper in Table 1 using a z-conditional demands approach reports such tests.

The distribution factors *SIncomeW1* and *SIncomeW2* are statistically significant in two demand functions and have the expected signs. The former proxies the bargaining power of the first wife and interestingly is shown to have a negative impact on both *PC-Husband* and *PC-Wife2*. The latter proxies the second wife's bargaining power and positively affects *PC-Wife2* and *PC-Children2*, as expected. Finally, *SDMarW1* proxies the seniority of the first wife and is associated with her having greater bargaining power. Results show it has a negative impact on *PC-Children2* and a positive one on *Millet* and *O-Food*. In short, the marginal effects are intuitively appealing and are consistent across the demand system.

3.6 Rationality tests based on proposition 2

Proposition 2 is a generalization of Proposition 1 to multi-person households. Testing begins with Restriction (8a), which implies that the three variables *SIncomeW1*, *SIncomeW2* and *SDMarW1* must have no influence on the demand system. Because the distribution factors are statistically significant in various demand functions we reject that bigamous households behave in a unitary way.

We next investigate whether collective rationality holds using the necessary Restriction (8b). The first step is to test whether (8b) holds when $J = 0$, i.e., that each individual demand function either does not respond to any of the distribution factors or responds to all of them. This restriction is clearly rejected since none of the demand functions responds to all three distribution factors. We thus move on to test whether Restriction (8b) is satisfied when $J = 1$. According to Restriction (8b), any given demand function that responds to the distribution factors may be inverted relative to one of the latter. Upon substituting the distribution factor, the remaining conditioned demand functions must either all be insensitive to the remaining distribution factors, or only be sensitive to a common subset. From Table 4, there are six possible inversions: *PC-Husband* and *PC-Wife2* relative to *SIncomeW1*, *PC-Wife2* and *PC-Children2* relative to *SIncomeW2* and finally, *PC-Children2* and *O-Food* relative to *SDMarW1*. For each of these possibilities, we tested whether the distribution factor constituted a weak instrument. The Cragg-Donald Wald *F* statistic is reported in Table 5. Based on the rule of thumb of Staiger and Stock (1997), the variable *SIncomeW2* is not a weak instrument in *PC-Wife2* and *PC-Children2*. However, based on the Stock and Yogo (2005) critical value for the 10% maximal IV size (=16.38), we do not reject that *SIncomeW2* is a weak instrument of *PC-Wife2*. This instrument is also weak accordingly to the critical value associated to a 10% bias of Nagar as suggested by Montiel and Pflueger (2013) (=23.1). Because of these mixed results, and in order to show how to implement Restriction (8b) with $J = 1$, we carry out the analysis and invert *SIncomeW2* and *PC-Wife2*. We next substitute out the latter in the unconditional demand functions that respond to the distribution factors, namely *PC-Husband*, *PC-Children2* and *O-Food*. The resulting *z*-conditional demand functions were estimated by 2SLS and the results are reported in Table 6.

The parameter estimates of the z_1-conditional demand functions are very similar to their unconditional counterpart. The distribution factor *SIncomeW1* remains statistically significant in *PC-Husband* while the same holds for *SDMarW1* in *PC-ChildrenW2* and *OFood*. This is at odds with Restriction (8b) when $J = 1$. Therefore,

Table 5 Tests based on proposition 2–bigamous households

Demand	PC-husband	PC-wife2	PC-children2	O-food
H$_0$: SIncomeW1 is a weak instrument				
Cragg-Donald Wald F statistic	8.390	4.605		
(10% maximal IV size)	(16.380)	(16.380)		
(tau = 10% with confidence level of 5%)	(23.110)	(23.110)		
H$_0$: SIncomeW2 is a weak instrument				
Cragg-Donald Wald F statistic		15.229	16.940	
(10 % maximal IV size)		(16.380)	(16.380)	
(tau = 10% with confidence level of 5%)			(23.110)	
H$_0$: SDMarW1 is a weak instrument				
Cragg-Donald Wald F statistic			9.157	4.784
(10 % maximal IV size)			(16.380)	(16.380)
(tau = 10% with confidence level of 5%)			(23.110)	(23.110)

conditionally on the assumption that *SIncomeW2* is not a weak instrument of *PC-Wife2*, collective rationality is rejected.[26]

3.7 Rationality tests based on CE2006

As with monogamous households, we begin by testing unitary rationality. Restriction (9a) posits that $rank[D_\mathbf{z}\mathbf{x}(\mathbf{z})]$ must be equal to zero for this to hold. The test yields $F(10,1420) = 4.85$ with a very small P-value. Unitary rationality is thus strongly rejected. We next test $H_0:rank[D_\mathbf{z}\mathbf{x}(\mathbf{z})] = 1$ using the bootstrapped Li (1991) statistic. The sample value of the statistic is 0.1018 with a P-value of about 0.000. Once again, the null assumption must be rejected. This is consistent with our previous result based on Restriction (8b) for $J = 0$. Finally, we move on to test $H_0:rank[D_\mathbf{z}\mathbf{x}(\mathbf{z})] = 2$. This is equivalent to testing there are three decision-makers in the household. The sample statistic is equal to 0.017 and its P-value is about 0.000. Rejection of the hypothesis thus implies rejection of collective rationality, which is consistent with the result from our Proposition 2.

4 Conclusion

The collective household model has become one of the main paradigms to conduct empirical research on consumption decisions by multi-person households. There are good reasons for that: it is based on relatively innocuous assumptions, and assuming these hold, it allows investigating intrahousehold impacts of numerous policies. Yet, one can not help but be concerned about the falsifiability of the model as it is seldom if ever rejected in the empirical literature. Such overwhelming evidence in favor of

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[26] We acknowledge that the approach we use may raise questions about the presence of a pretest bias, as the choice of which demand to invert depends on the statistical significance of the estimated coefficients. Note that this issue is present in all the studies that use the *z*-conditional demand condition approach.

Table 6 2SLS estimation of z_1-conditional demands - polygamous households

Variables	PC-husband	PC-children2	O-food
PC-wife2	−0.049	0.609***	0.277
	(−0.256)	(3.103)	(0.274)
Intercept	−0.987	0.575	−2.655
	(−1.320)	(0.740)	(−0.579)
Dakiégré	0.275***	−0.124	0.921**
	(3.479)	(−1.422)	(2.008)
Pelegtanga	0.210*	−0.078	0.359
	(1.976)	(−0.783)	(0.707)
Rallo	0.009	0.014	0.271
	(0.131)	(0.168)	(0.542)
Yako-1	0.116	0.0588	0.473
	(1.440)	(0.551)	(0.717)
Muslim	0.047	0.031	0.069**
	(0.719)	(0.400)	(2.224)
Age husband	−0.012	−0.048	0.140
	(−0.240)	(−0.999)	(0.713)
Age wife1	−0.045	0.099*	−0.151
	(−0.891)	(1.763)	(−0.613)
Age wife2	−0.088	0.043	0.286
	(−1.558)	(0.702)	(0.802)
Children wife1	0.057	−0.045	−0.772
	(0.465)	(−0.290)	(−1.153)
Children wife2	−0.066	0.244	0.870
	(−0.551)	(1.366)	(0.772)
ln(Total expenditures)	1.736	−0.942	4.110
	(1.356)	(−0.720)	(0.529)
ln(Total expenditures)^2	−0.072	0.040	−0.157
	(−1.336)	(0.733)	(−0.485)
Share income wife1	−1.091***	0.377	−0.382
	(−2.630)	(0.992)	(−0.155)
Share Duration Marriage Wife1	−0.317	−0.664**	3.258**
	(−1.275)	(−2.599)	(2.291)
Observations	117	117	117

t-statistics in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

the collective model may eventually stray many from investigating the foundations of the model toward assuming it holds, irrespective of the environment under investigation.

We suspect the under-rejection of the collective model is primarily due to the manner in which its underlying *theoretical restrictions* are translated into *statistical*

restrictions. Indeed, most papers investigate the collective model using a test procedure that was proposed by BBC2009. Yet the procedure requires that in any given demand system all functions respond to at least one common distribution factor. This implies that all distribution factors impact on all demand functions. This assumption is scarcely met in the empirical literature. Most papers simply ignore this and thus conduct tests based on a false premise.

In this paper, we provide a new falsifiable restriction which extends BBC2009's approach insofar as it does not require a distribution factor to affect each equation of a demand system. In the case of a two-person household, this (all or nothing) restriction imposes that each demand function is either affected by all distribution factors or by none of them. We derive a set of testable conditions and fully characterize collective rationality, assuming no variations in prices. Moreover, our approach is generalized to households comprising potentially more than two members. We provide a brief and informal meta-analysis that suggests that much of the evidence in favour of the collective rationality in the empirical literature fails to satisfy our new restriction.

We illustrate the usefulness of our approach by investigating efficiency in allocation of consumption within monogamous and bigamous households in rural Burkina Faso. Social and cultural environments as well as institutional arrangements are likely to impede the enforcement of efficient marriages. We thus do not expect, *a priori*, outcomes to be efficient. Based on our proposed test procedure and on a test of Chiappori and Ekeland (2006)'s rank condition, rationality is found not to hold for monogamous and polygamous households alike. We next proceed to test rationality for monogamous households using the test procedure of Bourguignon et al. (2009) while neglecting the fact that none of the distribution factors are statistically significant in every demand functions. Collective rationality is then (falsely) found to hold for monogamous households.

An important conclusion that can be drawn from this paper is that the collective model is empirically falsifiable: its underlying assumptions translate into non-trivial constraints that may be rejected in particular cases. Appropriately accounting for the latter may reveal that far fewer households behave efficiently than what the current literature suggests.

Recent work (e.g., Lechene and Preston 2011) has shown that non-cooperative models with public goods or externalities may impose restrictions on household behavior. A natural extension to our paper would be to develop and take to data a general model that has the collective and the non-cooperative (Nash) models as particular cases. Rigorous testing of competing sets of constraints would enhance our understanding of household behavior (see Naidoo 2015).

Compliance with ethical standards

Conflict of interest The authors declare they have no conflict of interest.

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