Decision-making by households

V. Joseph Hotz
Duke University

Evan Peet
Duke University

Duncan Thomas
Duke University

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Abstract

Understanding how individuals within households combine different needs, aspirations and preferences in the allocation of resources remains a key unresolved issue in models of family behavior in the population sciences. Using specially-designed population-level longitudinal survey data from Indonesia, we test models of co-operative decision-making by households. We validate our model by establishing that the behavior of single-adult households is consistent with predictions from economic models of individual choice and may be treated as a "unitary" decision-maker. In households with more than one adult, not only are the predictions of the unitary model rejected, but we also reject the predictions of a model that assumes household resource allocations are Pareto efficient. To interpret this evidence, we explore decision-making in the face of adversity. In the face of shocks, single-adult households tend to reach out to others whereas multiple-adult households tend to consolidate decision-making authority. Decision-making by households depends not only on the characteristics of members and their bargaining power but also the environment in which those decisions are made.

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1 Introduction

Understanding how individuals within households combine different needs, aspirations and preferences in the allocation of resources remains a key unresolved issue in models of family behavior in the population sciences. Whereas the theory of consumer demand is predicated on axioms of preferences of individuals, the application of the theory to decision-making by households calls for additional assumptions. The most common assumptions in the empirical literature are that all members of a household share the same preferences or there is one household member who makes all decisions. The assumptions of the 'unitary model', which are observationally equivalent for many empirical implementations, have been rejected in a wide array of settings. Alternative models treat the household as a collective of individuals and make assumptions about the mechanisms that underlie decision-making within the household. These include co-operative and non co-operative bargaining models (McElroy and Horney, 1981; Lundberg and Pollak, 1993) and, more recently, 'collective models' that assume household allocations are Pareto efficient (Chiappori, 1988). Whereas the collective model places only mild restrictions on behavior of household members, the implications of the model for resource allocation provide a series of powerful empirical tests that yield important insights into the nature of decisions and number of decision-makers in the unit. This paper tests those implications using uniquely rich longitudinal survey data on household expenditures and prices that we collected in Indonesia.

Estimates of demand systems are used to form estimates of the pseudo- Slutsky matrix which, following Browning and Chiappori (1998), lies at the center of our tests. We begin with tests of the unitary model of the household separating households into those with one decision-maker from those with more than one decision-maker. The implications of the unitary model for households with one adult are not rejected. This can be interpreted as validation of the empirical specification of the model. In contrast, the unitary model is rejected for households with more than one adult. Furthermore, the implications of the collective model are also rejected for these households. These results contrast with those in the literature; see, for example, Browning and Chiappori (1988) and

Rangel (2008). Apparently, in rural Indonesia, decisions in multiple-adult households are neither made by one person nor efficient in the sense that one decision-maker in the household could be made better off with no other decision-maker being made worse off. We investigate potential reasons for this departure from efficiency. Specifically, in the face of adverse circumstances, such as pestilence or drought, single adult households draw on other individuals in making decisions about resource allocation while multiple adult households consolidate that authority into the hands of fewer individuals.

The next section places this research in the context of the literature, describes the unitary and collective models of decision-making and highlights the empirical implications of the models. The following describes how these implications are tested. We then discuss the data and present the empirical results.

2 Model

Decision-making of groups is an active area of inquiry in economics with a long history that stretches back to at least Leontief (1933) and Lerner (1934) who represented the preferences of groups by community indifference curves. Samuelson (1956) pointed out that interpretation of welfare changes in this context called for additional assumptions – all community members share the same preferences or one member makes all decisions. In his seminal work on the household and family, these assumptions were invoked by Becker (1965, 1981).

To illustrate, begin with a welfare function, W, which flexibly combines preferences, u, of J individuals who are members of a household (or other decision-making unit):

$$W = W(u^1(c^1,...,c^J,G;\phi),u^2(c^1,...,c^J,G;\phi),...,u^J(c^1,...,c^J,G;\phi)) \quad (1)$$

The vector c^k represents private consumption by individual k and G is a vector of public goods shared by household members. Observed characteristics, such as demographics, and unobserved characteristics, such as tastes, are reflected in the vector φ. In general, the utility of person j depends on own consumption, c^j, the consumption of all others, public goods as well as the observed and unobserved characteristics, φ of j and all other household members.

In the unitary model, it is assumed that the individuals in the household share common preferences or one member makes all decisions so that the household decision problem is, without loss of generality:

$$\max_{C} W = u^j(c^1,...,c^J, G;\ \phi) \tag{2}$$

$$\text{subject to}: I = e = P' \cdot C$$

where I is total household income, e is total expenditure and P is a vector of prices, one for each of 1….S goods and C is total consumption of the household:

$$\sum_{j=1}^{J} c^j + G = C \tag{3}$$

The inclusion of G, the public good, though excluded in some models, is benign since almost any good can be thought of has having some private and at least some public component. Income as a function of wages, w, time endowment, T, non-labor income, y^j, and maximized household production profits, π^*, as well as total household expenditure, e, are defined, respectively, as:

$$\sum_{j=1}^{J}(w^j T + y^j) + \pi^* = I \tag{4}$$

$$I = P' \cdot C = e$$

The collective model builds on the axiom of Pareto efficiency and very little else making it a very general representation of household decision making.[1] The Pareto efficiency assumption is justified by the observation that interactions within the household can be viewed as a repeated game and repeated games often exhibit the long run equilibrium of cooperation (see Browning and Chiappori (1998)). The model allows for preferences to be heterogeneous and the individual weights, $\mu_j(P, I)$,

[1]Chiappori (1988) also describes testable predictions of income effects

hereafter referred to as Pareto weights, associated with each individual's utility are zero-homogeneous functions of environmental factors (such as prices and income). Building on the notation already presented and following Browning and Chiappori (1998) as well as Rangel (2004b), the collective model can be described as a weighted sum of household member's utilities subject to an income constraint.

$$\max_{C} W = \mu_1(P,I)u^1(c^1,...,c^J,G;\phi) + \sum_{j=2}^{J}\mu_j(P,I)u^j(c^1,...,c^J,G;\phi) \qquad (5)$$

$$\text{st}: I = P' \cdot C = e$$

This flexible framework creates a sequential approach to testing: first, test the special case - the unitary model - and, in the case of rejection, test the more flexible case - the collective model. More importantly, the assumption of Pareto efficiency in the collective model has been shown in Browning and Chiappori (1998) to produce a specific form of the Slutsky matrix thus providing a robust set of tests which exploit price variation.

2.1 Testable Predictions

A key implications of utility theory, the symmetry and negative semi-definiteness of the Slutsky matrix, should hold for individuals as well as households that operate in a unitary fashion. However, the symmetry of the Slutsky matrix has been rejected in several studies using household data (refer to the discussion in the introduction regarding the studies performed by Blundell, Paschardes and Weber (1993), Browning and Meghir (1991) and Browning and Chiappori (1998)). Besides symmetry, the unitary model also implies that the distribution of income within a household should not affect the household’s demand for any particular good. This leads to the tests of income pooling that have been performed in studies such as Thomas (1990), Schultz (1990) and Duflo (2000). Each of these have rejected the unitary model of the household. Generalizing from the unitary framework we arrive at the collective model. According to the model, which begins with the assumption of Pareto efficiency, a matrix containing household demand responses to price changes will have a predictable form in spite of heterogeneous preferences within the household. This is the remarkable conclusion reached by Browning and Chiappori (1998). To see this, first consider the collective model and it's solutions: the Marshallian demand functions, ψs.

$$\max_{C} W = \mu_1(P,I)u^1(c^1,...,c^J,G;\phi) + \sum_{j=2}^{J}\mu_j(P,I)u^j(c^1,...,c^J,G;\phi) \qquad (6)$$

$$\text{subject to}: I = P' \cdot C = e$$

$$\psi_s(P,e^*;\phi) = c_s(P,e^*,\mu(P,e^*);\phi)$$

e^* is the household expenditure at the optimal level of consumption. Differentiating the demand functions with respect to a price change in good r, then breaking the derivative up into component parts and regrouping we see that the demand response is a function of the traditional substitution and income effects as well and a new component containing the impact of the Pareto weights.

$$\psi_{sr} = \frac{\partial \psi_s}{\partial p_r} + \frac{\partial \psi_s}{\partial e^*}c_r$$

$$\psi_{sr} = [\frac{\partial c_s}{\partial p_r} + \frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial p_r}] + [\frac{\partial c_s}{\partial e^*} + \frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial e^*}]c_r$$

$$\psi_{sr} = [\frac{\partial c_s}{\partial p_r} + \frac{\partial c_s}{\partial e^*}c_r] + [\frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial p_r} + \frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial e^*}c_r] \qquad (8)$$

The first component from equation (8), $[\frac{\partial c_s}{\partial p_r} + \frac{\partial c_s}{\partial e^*}c_r]$, is the same as the elements of the traditional Slutsky matrix which reflects both a substitution effect due to the price change and the income effect due to the change in real income and expenditure. The second component from equation (8), $[\frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial p_r} + \frac{\partial c_s}{\partial \mu}\frac{\partial \mu}{\partial e^*}c_r]$, arises because of the Pareto weights. This component contains the resulting change in the attractiveness of the outside options due to the price change. For example, consider an Indonesian farm household containing individuals with differentiated talents and preferences. Assume each individual has varying abilities in the production of different crops and each is responsible for producing the crop best suited to his or her abilities. The relative price increase of one good will make the happiness of the individual in charge of it's production relatively more important and, simultaneously, increase the attractiveness of his or her options outside of the household. Alternatively, μ^j can be interpreted as pure income effects from intra-household lump sum transfers, allowing it's effects to be seen as income redistribution effects.

Following the previous formulation, the collection of the observed price responses will be defined as Ψ and called the Pseudo-Slutsky matrix with the traditional Slutsky price and expenditure component defined as Σ and the new income redistribution component defined as Ω. Recall that there are S goods.

$$\begin{bmatrix} \psi_{11} & \psi_{12} & \cdots & \psi_{1S} \\ \psi_{21} & \psi_{22} & & \\ \vdots & & & \\ \psi_{S1} & & & \psi_{SS} \end{bmatrix} = \Psi = \Sigma + \Omega \tag{9}$$

Utility theory shows that Σ must be a symmetric matrix but this does not mean the the observed price responses, Ψ, will be symmetric; a fact which explains the rejections of Slutsky matrix symmetry in the literature. Although Σ and Ω cannot be separately identified, the symmetry of Σ allows us to difference the observed price responses by their transpose and obtain an observable matrix, M, with testable implications.

$$M = \Psi - \Psi' = (\Sigma - \Sigma') + (\Omega - \Omega') = \Omega - \Omega' \tag{10}$$

The first testable implication is that under the unitary model $M = 0$ since Ω is 0 if the household is a dictatorship (it is equivalent to test the symmetry of M). Therefore, the first step in addressing the households decision process is testing the null hypothesis that $M = 0$. A rejection of this hypothesis is a rejection of the unitary model.

The other testable prediction is just a bit more complicated. Essentially, if the rank of M is no more than two times the total number of household members minus one ($2 \times (J-1)$) then the collective model holds, or the household's resource allocations are Pareto efficient. From Browning and Chiappori (1998) the **SRk proposition** summarizes the implications of the collective rationality model:

PROPOSITION SRk: Consider a set of S goods. Assume that the household has $J = k + 1$ members where $k < S - 1$. In the collective setting the Pseudo-Slutsky matrix, Ψ, is the sum of a symmetric matrix, Σ, and a matrix of rank no greater than k (SRk, Symmetric plus Rank k).

Since Σ and Ω are not identified the SRk proposition also implies that, under the collective model, the matrix M is anti-symmetric ($M = -M'$) and it's rank is an even number. By the properties of matrix rank,

$$rank(M) \leq rank(\Omega) + rank(\Omega')$$

$$rank(M) \leq 2 \times rank(\Omega)$$

$$rank(M) \leq 2 \times (J - 1) = 2 \times k$$

In summary, tests following this order are employed:

i) M 's symmetry or equality with zero is tested. If rejected the unitary framework is ruled out.

ii) M 's rank is tested for even values. If $rank(M) > 2 \times (J - 1)$ then collective model is rejected.

2.2 Estimation of the Demand System

The section introduces the demand system that has been the workhorse of this literature and a flexible generalization that will be used in the estimation. Empirical methods that will be used to test the rank of the Pseudo-Slutsky matrix are also described.

Previous research has employed the following Quadratic Almost Ideal Demand System as the parameterization (though any version of the Almost Ideal Demand System is a valid parameterization; see Browning and Chiappori (1998) and Rangel (2004b)).

$$\tilde{c}_s = \alpha_s + P'\delta_s + \beta_s[ln(e) - a(P)] + \gamma_s[\frac{(ln(e) - a(P))^2}{b(P)}] + \varepsilon \quad (11)$$

$$a(P) = \alpha_0 + P'\alpha + \frac{1}{2}P'\Delta P \quad (12)$$

$$b(P) = exp\{\beta' P\} \tag{13}$$

$\widetilde{c}_s$ denotes the budget share for good s, P is the vector of log prices and e is per capita total expenditure.

As stated in Browning and Chiappori (1998) the Quadratic Almost Ideal Demand System is not the only demand system that can be used and, in fact, it is preferable to use more non-parametric methods. QUAIDS imposes a quadratic structure on the relation between the log of per capita expenditure and the budget share for each good. Though this is somewhat flexible and has been shown to be appropriate in many instances, more flexible relationships between expenditure and budget share can be employed without negative consequence. The method employed here is a piecewise polynomial, otherwise known as a spline. In this formulation the domain of log per capita expenditure is divided into multiple parts with a function fitted to the data contained within each part of the domain[2]. Let $S_l(ln(e))$ be the l'th piecewise polynomial of the log of per capita expenditure, then:

$$\widetilde{c}_s = \alpha_s + P'\delta_s + \beta_{s1}S_{s1}(ln(e)) + \beta_{s2}S_{s2}(ln(e)) + \ldots + \beta_{sl}S_{sl}(ln(e)) + \varepsilon \tag{14}$$

The parameters of interest are the δ_s's. Let Δ be the $S \times S$ matrix of log price coefficients and $\delta_{s'}$ is a row in Δ, or,

$$\Delta = \begin{bmatrix} \delta_{1'} \\ \delta_{2'} \\ \vdots \\ \delta_{S'} \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & \ldots & d_{1S} \\ d_{21} & d_{22} & & \\ \vdots & & & \\ d_{S1} & & & d_{SS} \end{bmatrix} \tag{15}$$

These are the observed price response coefficients which will be used to test the implications of the unitary and collective models. It is important to note that Δ is not equivalent to $\Psi = \Sigma + \Omega$ or to $M = \Omega - \Omega'$ but, as established by Browning and Chiappori (1998), M is SRk if and only if Δ is SRk.

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[2] The estimation in this paper divides the domain into four parts which, upon inspection, seems to adequately account of the non-linearities in the log of per capita expenditure. Various divisions of the domain have been explored without any distinguishable changes to the results.

Furthermore, we will also impose homogeneity. Adding up is implied by the data construction thus we can choose a numeraire good and normalize all other prices by the price of this good.[3] Therefore, $S-1$ systems of equations are estimated and the matrix Δ is $(S-1)\times(S-1)$ in dimension.

The population is divided into various groups depending on the number of potential decision-makers within the household and the demand system is estimated for each group. This is done for two reasons. First, performing the estimation for each group allows for some implicit flexibility in the parameters; it essentially divides the population into types and takes a step towards the flexibility of a random coefficients model. Although it would be ideal to allow the parameters to vary by household this would require some assumptions regarding the functional forms of the parameters and would greatly increase the computational burden. Secondly, grouping by household composition allows the tests to compare the actual number of decision-makers within household to the number of potential decision-makers, rather than describing sample wide averages.

In addition to the estimation of the household demand system this paper also investigates the decision process within households facing adversity. Obviously, adversity is a very broad term and any two adverse situations faced by different households will undoubtedly differ in type and severity. Furthermore, the data does not contain information on all possible trials that a household may face. Regardless, we believe the question of how households allocate resources and make decisions in adverse circumstances is worth considering. This paper analyzes the effect of exogenous, unpredictable shocks to household welfare such as: drought, pestilence, rodent infestation and any other natural disasters.

[3] For the purposes of this paper, the good selected as the numeraire is "Prepared Food". The groups of goods used in the empirical implementation are discussed in more detail below.

2.3 Estimation Issues

The following issues surrounding the estimation of demand will be discussed here: sub-aggregation, separability and endogeneity.

In order to more closely approximate a complete demand system with reasonable separability assumptions (which are discussed below) the estimated goods are actually sub-aggregates. The demand system is composed of ten sub-aggregates, five food and five non-food. For example, the grain sub-aggregate is composed of, among other things, rices, noodles, flour and nuts. Protein is composed of beef, chicken, fish, tofu and eggs. Besides grain and protein, the other three food sub-aggregates are: fruits and vegetables, high calorie foods and prepared foods. The five non-food sub-aggregates are: household goods and expenses (including rent), utilities, clothing, human capital and entertainment. The corresponding prices for each of these sub-aggregates are weighted averages of the component goods.[4]

The goods in the demand system are assumed to be separable from both the labor/leisure decision and intertemporal allocation decisions. Past research has employed different separability assumptions and addressed them by limiting the sample; Browning and Chiappori (1998) limit their sample to only include single adults and couples living alone that are also labor force participants and Rangel (2004b) limits to only include farm households. In the context of Central Java, Indonesia these additional limitations would be arbitrary and would not provide additional validity to the estimates. First, labor force participation is more difficult to define in an area with high levels of household production and employment is more fluid. Second, although about half of the households in the sample do not have farm land many of them are related to households with farms and contribute to farm production so to classify them as non-farm households is not very clean. The separability of intertemporal allocations has been ignored by past research and although it it is an area of very interesting future research, because of the complexity of the problem this study will assume its separability.

[4] The weights are derived from a more comprehensive, contemporary survey of consumption in Indonesia, SUSENAS.

There are at least three potential sources of endogeneity which could affect the validity of the above estimation approach. One potential source of endogeneity is grouping. Grouping based on household size and composition may be endogenous to the decision process but the benefits to stratification outweigh the potential costs. Without it the theoretical prediction of the rank of the Pseudo-Slutsky matrix cannot be used and little can be said regarding the efficiency of the household's allocations. Additionally, because many households in the survey are producers, prices have the potential to be endogenous. However, we do not believe this is a problem for two reasons: competitive markets and price construction. The vast majority of households produce rice and other farm products which are part of a competitive market where producers have minimal ability to affect prices. Furthermore, the prices used in estimation are medians specific to time and place. Because of these reasons, the prices used in estimation are unlikely to be endogenous.

The endogeneity of expenditure is more complicated. There are at least two reasons to think that total household expenditure might be endogenous. First, unusually high or low expenditure on a good by the household will affect both the error and the total expenditure, thereby inducing a correlation between expenditure and the error. The structure of the data allows for the various types of goods to be either aggregated or disaggregated in order to reduce the lumpiness of purchases. First, food purchases are likely to be less lumpy and they are aggregated from weekly consumption to monthly. Then, data on more durable goods are collected for either the past month or the past year, making the presence of zeros in expenditure less likely. Other studies have used net income to instrument for the potential correlation between expenditure and the errors. However, since net income is a function of the labor/leisure decision it may also be correlated with the error term in the demand equation. The second reason that expenditure may be endogenous is the endogeneity of the sale and production of household goods (from the farm or otherwise). Ideally, the model would account for this endogeneity through the use of profit maximization and a production function similar to the model known as the agricultural household model and described in Singh, Squire and Strauss (1986). However, the level of complexity increases exponentially when incorporating these features into the model. Since farming is a multi-period process with uncertainty, intertemporal allocations as well as risk would become issues. Also, the choice of crops in a multi-crop environment, the types and intensity of inputs to use as well as investment in technology would either be features of the model or require assumptions about producer behavior. Hopefully, this will be an area of fruitful future research but for the purposes of the current paper household expenditure is assumed to be exogenous.

2.4 Empirical Implementation of the Tests

This section describes the testing strategy that we have adopted. To test the unitary model M's symmetry must be tested and to test the collective model the rank of M must be determined. The rank of deterministic matrices is found by counting the number of linearly independent columns/rows by getting the matrix into row reduced Echelon form or performing a singular value decomposition and counting the number of non-zero diagonal elements. When the elements of the matrix are estimated with variance the determination of the rank becomes difficult.

It is necessary to first test whether M is symmetric. We perform both individual and joint tests of symmetry. Pairwise tests of symmetry compare each element in the lower triangle of M to its counterpart in the upper triangle. The joint test is performed using the following Wald statistic with $w_1 = \frac{(S-1)\times S}{2}$ degrees of freedom:

$$Wald_1 = [Rvec(\hat{M})]'[RVR']^{-1}[Rvec(\hat{M})] \rightarrow \chi^2_{w_1} \qquad (16)$$

R is a selection vector and V is the variance-covariance matrix of the elements in M.

We turn next to three tests of matrix rank that we will implement.[5]

The first test follows Browning and Chiappori (1998) who show that M having 2 linearly independent columns/rows is equivalent to testing:

[5]There is an extensive literature on methods to assess the rank of a matrix. See, for example, Gill and Lewbel (1992), Cragg and Donald (1997), Robin and Smith (2000) and Ratsimalahelo (2003).

$$h(m_{sr}) = m_{sr}m_{12} - m_{1s}m_{2r} + m_{1r}m_{2s} = 0 \qquad \forall \quad r > s > 2 \tag{17}$$

This results in $w_2 = \frac{(S-2)\times(S-3)}{2}$ restrictions and the following non-linear Wald statistic:

$$Wald_2 = h(m_{sr})'[\frac{\partial h}{\partial m_{sr}} V \frac{\partial h}{\partial m_{sr}}']^{-1} h(m_{sr}) \to \chi^2_{w_2} \tag{18}$$

The key issue for this study is that the test is only valid when testing $H_0 : rank(M) \leq 2$.

The next test is based on the bootstrap of the borderline singular value from Bullock (1995). Denote the full sample estimate of M as $\hat{M}$. Also denote the bootstrapped estimates of M as $\{\hat{M}_b\}_{b=1}^B$. The singular values of each bootstrapped estimate can be easily obtained and will be denoted $\{\hat{D}_b\}_{b=1}^B$. The borderline singular value is the singular value that should be zero if the null hypothesis is true. For example, consider the hypothesis $H_0 : rank(M) \leq r = 2$. If the null hypothesis holds then M should have two non-zero singular values. Since the singular value decomposition arranges the singular values on the diagonal in descending order the singular value of interest is placed in the $r+1$ position - in this case it is the element $(3,3)$ in $\hat{D}_b$. And with the set of borderline singular values denoted as $\{\hat{d}_{b,r+1}\}_{b=1}^B$ we almost have enough notation to fully describe this test. Let $\overline{M}$ be the mean of the bootstrapped estimates of M and let A and B denote the matrices flanking the singular value matrix D in the singular value decomposition: $M = ADB'$.

Essentially, the test creates cutoff values for the borderline singular value such that values less than the cutoff provide evidence in support of the null hypothesis. The trick is constructing those cutoff values. The construction begins with the singular value decomposition of $\overline{M} = \overline{A}\overline{D}\overline{B}'$. Next D^* is defined as $\overline{D}$ except that the $S-r$ smallest singular values are substituted by zeros. This leads to $M^* = \overline{A}D^*\overline{B}'$. Finally, the matrix that will give the cutoff values is:

$$M_b^H = M^* + [\hat{M}_b - \overline{M}] \tag{19}$$

There is an M_b^H for each bootstrap and the decomposition of each of these yields the constructed cutoff singular values, $\{\hat{d}_{b,r+1}^H\}_{b=1}^B$. From this the p-value of the test is defined:

$$p = \frac{1}{B}\sum_{b=1}^{B} 1\{\hat{d}_{b,r+1}^H > \hat{d}_{b,r+1}\} \tag{20}$$

A potential issue for this test is a size distortion due to the fact that singular values are not pivotal statistics. The same critique applies to the test that follows.

The last test, which is similar to the previous test of singular values, constructs cutoffs for the singular values of the bootstrapped estimates of M, but goes about it in a different way. From Konstantinides and Yao (1988) the fundamental assumption behind this test is that $\hat{M}$ can be thought of as a function of the true M and some independent, identically distributed perturbations in the form of E. The critical theorem is that with $M, \hat{M}$ and E such that $\hat{M} = M + E$ and respective singular values, $\hat{d}_i, d_i, \varepsilon_i$, arranged in descending order, the following relationship holds:

$$|\hat{d}_i - d_i| \leq \varepsilon_i = \| E \|_2 \tag{21}$$

As usual, $|\hat{d}_i - d_i|$ denotes the norm of the difference but $\| E \|_2$ denotes the 2-norm of E defined as:

$$\| E \|_2 = max(\frac{\| E \|_2}{\| x \|_2}) = \varepsilon_1 \tag{22}$$

More simply, the 2-norm of E is equal to its largest singular value. Furthermore, since under the null hypothesis the borderline singular value of M is zero the following relationship for the borderline singular value of $\hat{M}$ holds:

$$|\hat{d}_{r+1} - d_{r+1}| = \hat{d}_{r+1} \leq \varepsilon_1 \tag{23}$$

All that is left is to determine the value of ε_1. This is obviously not identified with observable data but it can be bounded. The tightest bounds given by Konstantinides and Yao (the ones used in this paper) are defined as follows:

$$\sqrt{\theta}\sigma \le \varepsilon_1 \le S\sigma \tag{24}$$

σ is the standard deviation of the elements of E and θ is the critical value of a chi-squared distribution test with S degrees of freedom and hence it is a function of the level of significance to the test, α. Both $(.05,.01)$ will be used as values for alpha as well as the estimated value of σ. The p-values of the test are calculated in the following way:

$$p = 1 - \frac{1}{B}\sum_{b=1}^{B} 1\{\sqrt{\theta}\sigma \le \hat{d}_{b,r+1} \le \varepsilon_{b,1} \le S\sigma\} \tag{25}$$

3 Empirical Results

3.1 Data

Prior to discussing the empirical results, the data are described. In order to estimate the demand system as presented in the models above, detailed consumption and expenditure data as well as price data with sufficient variation are needed. The Work and Iron Status Evaluation, or WISE, contains both a very detailed, multiple wave survey of households and a survey of prices. WISE is a random-assignment treatment and control intervention in Central Java Indonesia, specifically the Purworejo District. (Thomas et al, 2010). The survey and treated individuals experience increased physical and psychological health as well as economic success due to iron supplementation. The detailed collection of household characteristics including composition and expenditure as well as extensive price data make it an ideal dataset to use in answering the question at hand.

Purworejo is located on the southern coast of Java in Indonesia and is home to about 1 million people. As seen in Table 1, the majority of households in the sample live in rural areas. 46% of single adult households live in rural areas but for all other household types over 75% of them are rural. Approximately 18,000 respondents living in 4,500 households were selected for the study sample. Starting in early 2002 with the pre-baseline survey each household was resurveyed every four months for nearly three years at which time the number of months between surveys became greater. The households were closely followed. Following the screening, 99.6 percent of the selected households participated in the pre-baseline survey. Almost 97 percent of households in the baseline survey were resurveyed in the following wave. Obviously, attrition in this survey is small but it is nonetheless important. Analysis of the relation between observable characteristics and attrition shows that slightly more men attrit than women and attrition is more likely during young adulthood than any other time. The most recent wave of the study was conducted in 2009, however the last wave included in this paper was conducted during 2007.

Table 1 provides a demographic description of the households in the sample for the four groups: single adult households, households with only two adult, households with two adults and children or any other individuals less than age 15, and households with more than two adults. The households are described by composition, age, location and education. Additionally, the average log per capita total expenditure by group is given as well as the percent of households that have experienced an unpredictable negative shock. The household surveys in WISE contain questions regarding whether or not the household has, in the last year, experienced adverse situations such as drought, famine, death in the family, loss of job, infestation and others. Only the unanticipated, random situations, such as drought and infestation, are included in the indicator of where the household has experienced a negative shock. Finally, the average size of each group by wave is given. Each household is included multiple times in the data, once each wave, so each observation in the data is a household in a certain wave. Note that the biggest differences are between single adult homes and all other types. Noticeably, the percent of single adults living in rural areas is much smaller than all other groups as well as the percent of single adults that have experience negative shocks. However, colinearity of these two variables is not a concern since the covariance between them for single adults is quite low, -.004.

Table 2 describes the average budget share allocations. Again, the largest differences seen in this table appear to be between singles and all other groups, most notably in regards to food. Single adult households devote much more of their budget to prepared foods than all other groups and less of their budget share to grains and protein. However, the overall allocation between food and non-food items is not much different among groups.

Table 3 shows the average normalized prices and their sample variation across communities and waves. The price survey was administered every three months recording prices of many goods including rice, cassava, oil, sugar, chicken, gas, household goods, farm equipment, clothes and many others. The price surveys in WISE attempt to obtain prices for the same brand, quality and size, and when they are not available close substitutes are identified and used. Prices in WISE therefore have low quality variation and few missing values (see McKelvey (2004) for a very thorough treatment of the potential pitfalls to quality variation in price data). Prices, as previously mentioned, are constructed first as weighted averages of the various component goods of the 10 sub-aggregates - grain, protein, fruits and vegetables, high calorie foods, prepared foods, household goods and expenses, utilities, clothing, human capital and entertainment. Additionally, the median price specific to time (date when the household was interviewed) and place (enumeration area) is used in order to eliminate potential endogeneity, measurement error and outliers. Finally, the prices are normalized by the price of a numeraire good, which in this case is the price of prepared food (note that prices can be negative due to their normalization). Despite the fact that much of the variation in prices is eliminated by only including the median price specific to time and place each price still contains a non- negligible amount of variation.

3.2 Estimated Demand System

The demand system from equation (16) is estimated using the method of seemingly unrelated regressions with $S - 1$ (nine) equations. In order to preserve the power of the estimation all observations in the dataset are used and each group (single adults, two adults, two adults and others and many adults) is distinguished by an indicator variable. Also, since each household is included multiple times in the data the standard errors are corrected for clustering by household. Furthermore, each equation in the system has the same control variables: district fixed effects (district being larger than the enumeration areas to which the prices are specified), household composition including how many adults, elders and children are in the home, education levels of the male and female heads of the household, the age of the heads of household and indicators of whether the household resides in an urban or rural location. The coefficients displayed in Tables 4a and 4b are from interactions between prices and the group indicator variables. The first two columns of Table 4a display the price coefficients for the grain equation for single adult households and all non-single adult households. The next four columns display the price coefficients in the grain demand equation for single adults, two adults, two adults and others and three or more adults homes'. Finally, in Table 4b, the estimated price coefficients for the grain equation for singles that have and have not experienced a negative shock and non-singles that have and have not experience a negative shock are displayed.

3.3 Pseudo-Slutsky Tests

As previously described, Tables 5, 6, and 7 depict tests of M; it's symmetry or equality with zero as well as it's rank. Table 5 shows the results of these tests for single adult households and non-single adult households, Table 6 shows the test results for single adult homes, two adults only homes, homes with two adults and others, and many adult homes, and Table 7 shows the test results single adult and non-single adult homes faced with adversity.

Beginning with Table 5, the first thing to notice is the joint test of symmetry for single adult homes. The null hypothesis of symmetry can be rejected at the 10% level but not at the 5% and 1% levels. Not rejecting the symmetry of the Pseudo-Slutsky matrix for a single adult home aligns with both intuition and the predictions of utility theory. However, symmetry is handily rejected for non-single adult households, which again aligns with intuition. Furthermore, in pairwise tests of symmetry the percent of rejections is much higher for non-single adult homes than single ones.

For the Browning and Chiappori Linear Dependence Test of H0 : rank(M) $\leq$ 2 we cannot reject the null hypothesis for single adult homes but for non-single adult homes the null hypothesis is again rejected. The rank of M corresponds intuitively with the number of decision-makers in the home, thus the test provides evidence that there are two or fewer decision-makers in the single adult home and more than two decision- makers in the non-single adult home. Additionally, the null hypothesis implies Pareto efficiency so we cannot reject the conclusion that allocations within the single adult home are Pareto efficient. However, a similar statement cannot be made of the non-single adult home. Because the non-single adult group contains all homes with two or more adults it is unclear what rejection of the null hypothesis implies regarding Pareto efficiency. The group must contain a specific number of potential decision-makers in order reach any conclusion regarding Pareto efficiency.

The other two tests are based on the bootstraps of the singular values of the matrix M. The advantage to these is that test of rank greater than two can be performed. However, they offer opposing results in this situation. First, the Borderline Singular Value Test rejects that the rank of the Pseudo-Slutsky matrix is less than two for both single adults and non-single adults. The null hypothesis that the rank is less than four is not rejected for single adult homes but is rejected for non-single adult homes. The Konstantinides Singular Value test does not reject the null hypotheses that the rank is less than or equal to two and four for both single adult homes and non-single ones. The majority of the evidence from these tests supports the null hypothesis that the rank is less than 2 for single adult homes. Also, the majority supports a rejection of the null hypothesis that the rank is less than 2 for non-single adult homes. Obviously, these results are not as clear as one would hope.

Table 6 presents the results of the same tests performed on single adult homes, homes with only two adults, homes with two adults and other individuals less than 15 years old, and homes with three or more adults. The tests of symmetry are not as conclusive as the previous tests. The p-values indicate the rejection of symmetry in all cases but the Wald statistic for single adult homes is much smaller than all the others, as is the percent of rejections of pairwise tests. Also, if a Schwarz critical value of (degrees of freedom × ln(sample size)) 305.62 is used then symmetry is not rejected for the single adult group - but its also not rejected for any other group.

The Browning and Chiappori Linear Dependence Test supports the prior results in the case of single adults, not rejecting the null hypothesis that the rank is less than or equal to 2. However, in the case of two adults the null is rejected implying that there may be more than two decision-makers in those homes and that the allocations are not Pareto-efficient. The same holds for households with two adults and other members of age less than 15. But the null is not rejected for households with many adults. This points to a conclusion reached also in Rangel (2004b) that in households of three or more adults there is a consolidation of decision authority.

The Borderline Singular Value tests reject both hypotheses for all groups. These rejections indicate a lack of Pareto efficiency. However, the Konstantinides Singular Value tests again contradict the Borderline Singular Value tests in most instances. These tests indicate Pareto efficiency in both single and two adult households. However, similar to both previous tests this test rejects Pareto efficiency for households with two adults and other members of age less than 15. And similar to the Browning and Chiappori test the null hypothesis that the rank of the Pseudo-Slutsky matrix is less than or equal to two is not rejected for households with many adults, providing additional evidence of a consolidation of decision authority.

Table 7 displays the results of the same tests performed on both single and non-single adult households that have either faced adverse, unpredictable circumstances such as drought, pestilence, rodent infestation and other natural disasters or not. The idea is to investigate how households respond to adverse situations and whether there are and changes to their decision making process. Without empirical research it is unclear whether household consolidate decision making authority or decentralize or if they change at all. As it turns out, the answer depends on the household's composition.

The majority of the evidence seems to indicate that single adult homes facing adversity open their decision-making to the influence of additional individuals while larger households consolidate the decision- making authority into fewer hands. The tests of symmetry support this story in the case of non-single adult homes but do not support the idea of single adult homes facing adversity involving others in their decision making because the null hypothesis is not rejected. However, for single adult homes the Wald statistic is much larger for those facing adversity leading to a rejection of the null and providing evidence of additional influence on decisions. Also, the Wald statistic for non-single adult homes that have experienced a negative shock is very small, again providing evidence that larger households consolidate. The Borderline Singular Value tests on single adults indicate a lack of Pareto efficiency both for those that experience shocks and those that do not but for non-single adult homes the tests indicate a consolidation of authority. The Konstantinides Singular Value tests indicate Pareto efficiency for single adult homes and for non-single adult homes there again appears to a consolidation of authority.

However, these results are not without caveats. First, adversity is difficult to define and, in essence, idiosyncratic. Adversity in this case is defined by unpredictable forces of nature but that is obviously not the only type of adversity that a household can face. This indicator of adversity may solely be selecting a specific group in the population that are more susceptible to nature's adversity. Also, referring to Table 1, the frequency of experiencing adversity is quite low so the tests may have insufficient power.

4 Conclusion

Households in the developing world, where the likelihood of more than two adults living under the same roof is much greater than in the developed world, are complicated structures. Understanding how households operate is important not only for accurate economic models and research but also to know how to direct policy interventions. This paper addresses both the unitary and collective models for households and extended families. The evidence, while not entirely consistent, indicates that single adult households do operate under the unitary model while larger households do not. This is consistent with the majority of past research regarding the unitary model.

However, much prior research has supported the collective model of the household while various tests within this paper reject that model. Udry (1996) and Owens (2001) cite apparent gender discrimination leading to the inefficient allocation of resources within the households of Burkina Faso. Due to the format of the tests presented in this paper, it is not possible to provide a reason for the observed inefficient allocations. That is left for future research. However, in support of prior research such as Rangel (2004b), there is evidence that households with multiple adults do not have as many decision-makers as adults, or that authority is consolidated within the household.

Also, by extending the analysis to households that have experienced drought, pestilence, and natural disasters, we have shown that the decision process under difficult circumstances differs from the norm. Single adult households appear to reach out, possibly to extended family, for assistance in the face of adversity, while larger households reduce the number of individuals in the home with decision-making authority.

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Table 1: Descriptive Statistics of Purworejo Indonesia

	Single Adult	2 Adults Only	2 Adults with others	3+ Adults
Demographics:				
Men 15-64 in Household	0.35	0.55	0.88	1.50
	(0.48)	(0.55)	(0.33)	(0.81)
Women 15-64 in Household	0.33	0.72	0.98	1.72
	(0.47)	(0.52)	(0.25)	(0.70)
Men 65+ in Household	0.09	0.42	0.08	0.28
	(0.29)	(0.49)	(0.28)	(0.46)
Women 65+ in Household	0.19	0.31	0.05	0.28
	(0.39)	(0.47)	(0.22)	(0.47)
Kids 0-4 in Household			0.51	0.31
			(0.61)	(0.53)
Kids 5-9 in Household			0.56	0.35
			(0.63)	(0.57)
Kids 10-14 in Household			0.62	0.39
			(0.67)	(0.60)
Household Size			3.69	4.62
			(0.82)	(1.37)
Male Head/Spouse Age	44.56	59.45	44.59	53.66
	(16.65)	(13.81)	(12.24)	(12.63)
Female Head/Spouse Age	47.54	55.60	39.38	48.52
	(16.97)	(13.17)	(11.60)	(11.84)
Male Head/Spouse Education	4.19	5.04	7.41	6.37
	(5.40)	(4.54)	(4.63)	(4.35)
Female Head/Spouse Education	47.54	55.60	39.38	48.52
	(16.97)	(13.17)	(11.60)	(11.84)
Percent Living in Rural Location	48	78	79	76
Per Capita Household Expenditure:				
Log Expenditure	6.12	5.60	5.35	5.26
	(0.82)	(0.73)	(0.67)	(0.67)
Negative Shock:				
Percent of Households Experienced	1	4	5	5
	(0.11)	(0.19)	(0.21)	(0.22)
Sample Size:				
Average Over All Waves	540	984	1066	2615

Each Survey of a household in a wave is an observation

Total number of observations: 46,843

Standard Errors are displayed in parenthesis

Table 2: Mean Percentage and Standard Errors of Budget Shares

	Single Adult	2 Adults Only	2 Adults with others	3+ Adults
Percent of Total Expenditure Devoted to:				
Grain	8.95	15.03	15.16	15.82
	(11.72)	(10.24)	(9.35)	(9.70)
Protein	3.82	8.25	7.99	8.10
	(6.33)	(6.77)	(5.79)	(5.70)
Fruit and Vegetable	4.36	6.80	6.79	6.34
	(5.51)	(5.11)	(4.79)	(4.46)
High Calorie	6.12	11.00	10.43	9.86
	(7.84)	(7.53)	(6.80)	(6.24)
Prepared Food	34.30	18.90	17.17	16.47
	(22.80)	(13.50)	(10.68)	(10.24)
Household Goods	15.21	11.49	11.27	10.79
	(13.54)	(12.41)	(10.99)	(11.09)
Utilities	7.76	7.36	6.60	7.21
	(8.63)	(7.69)	(6.74)	(6.89)
Clothing	2.55	2.09	2.59	2.50
	(2.70)	(2.22)	(2.09)	(2.16)
Human Capital	12.72	12.07	13.95	15.46
	(17.26)	(13.65)	(11.26)	12.37
Entertainment	2.24	2.73	2.74	2.78
	5.17	5.19	4.49	4.80
Overall Budget Shares:				
Food	57.60	60.15	57.50	56.60
	(21.80)	(19.90)	(17.50)	(17.60)
Non-Food	42.40	39.80	42.50	43.40
	(21.80)	(19.90)	(17.50)	(17.60)

Each Survey of a household in a wave is an observation
Standard Errors are displayed in parenthesis

Table 3: Means and Std Errors of Log Prices

Location and Date Specific Prices of:	
Grain	-1.85
	(1.46)
Protein	10.41
	(1.23)
Fruit and Vegetable	-0.14
	(1.39)
High Calorie	4.09
	(1.39)
Household Goods	-7.61
	(1.36)
Utilities	1.91
	(2.54)
Clothing	11.50
	(1.94)
Human Capital	-8.08
	(1.60)
Entertainment	4.99
	(1.81)

Standard Errors are displayed in parenthesis

Table 4a: Example of Estimated Demand System

	Single Adults	Non-Single Adults	Single Adult	2 Adults Only	2 Adults with others
Demand for Grain					
Price of Grain	-0.55	0.59	-0.32	0.34	0.60
	(0.18)	(0.06)	(0.17)	(0.11)	(0.12)
Price of Protein	1.99	1.62	1.95	1.82	1.51
	(0.24)	(0.09)	(0.20)	(0.15)	(0.12)
Price of Fruits and Vegetables	-0.45	-0.24	-0.52	-0.22	-0.27
	(0.20)	(0.05)	(0.18)	(0.10)	(0.08)
Price of High Calories	-0.37	-0.10	-0.33	-0.23	-0.03
	(0.20)	(0.06)	(0.17)	(0.13)	(0.12)
Price of Household Goods	-0.19	-1.82	-0.38	-1.58	-1.96
	(0.19)	(0.07)	(0.16)	(0.11)	(0.12)
Price of Utilities	0.05	0.05	0.05	0.00	0.00
	(0.07)	(0.02)	(0.05)	(0.03)	(0.02)
Price of Clothing	-0.10	-0.22	-0.14	-0.26	-0.20
	(0.11)	(0.02)	(0.09)	(0.04)	(0.04)
Price of Human Capital	-0.34	0.08	-0.29	-0.01	0.12
	(0.09)	(0.04)	(0.09)	(0.09)	(0.09)
Price of Entertainment	0.01	0.02	0.04	-0.04	0.08
	(0.10)	(0.02)	(0.08)	(0.06)	(0.04)

Standard Errors are displayed in parenthesis

Standard Errors are corrected for clustering by households

Table 4b: Example of Estimated Demand System

	Single no Shock	Single with Shock	Non-Single no Shock	Non-Single with Shock
Demand for Grain				
Price of Grain	-0.54	-2.67	0.60	1.23
	(0.18)	(2.68)	(0.06)	(2.72)
Price of Protein	1.99	0.38	1.60	3.95
	(0.24)	(3.05)	(0.09)	(3.20)
Price of Fruits and Vegetables	-0.47	2.77	-0.25	-3.40
	(0.20)	(3.05)	(0.05)	(3.07)
Price of High Calories	-0.39	0.16	-0.10	-1.08
	(0.20)	(5.45)	(0.06)	(5.52)
Price of Household Goods	-0.17	-2.35	-1.83	2.34
	(0.19)	(2.69)	(0.07)	(2.76)
Price of Utilities	0.05	3.87	0.06	-3.77
	(0.07)	(2.21)	(0.02)	(2.22)
Price of Clothing	-0.10	-0.27	-0.21	-0.18
	(0.11)	(1.05)	(0.02)	(1.09)
Price of Human Capital	-0.35	0.67	0.09	-1.64
	(0.09)	(1.14)	(0.05)	(1.10)
Price of Entertainment	0.02	-0.09	0.02	0.14
	(0.10)	(0.69)	(0.02)	(0.73)

Standard Errors are displayed in parenthesis

Standard Errors are corrected for clustering by households

Table 5: Tests of the Unitary and Collective Rationality Models: Single and Non-Single Households

	Single Adult	Non-Single Adult
Tests of Symmetry:		
Wald Statistic from Joint Test	50.03	415.49
P-Value	0.06	0.00
Percent of Pairwise Test Rejections	11	27
Tests of Collective Rationality:		
Browning and Chiappori Linear Test		
Rank less than or equal to 2		
Wald Statistic from Joint Test	31.12	128.49
P-Value	0.06	0.00
Borderline Singular Value Test		
Rank less than or equal to 2		
P-Value	0.01	0.01
Rank less than or equal to 4		
P-Value	0.14	0.01
Konstantinides Singular Value Test		
Rank less than or equal to 2		
(α=.05,σ=.2)	0.43	0.99
(α=.01,σ=.2)	0.43	1.00
Rank less than or equal to 4		
(α=.05,σ=.2)	0.86	1.00
(α=.01,σ=.2)	0.94	1.00

Table 6: Tests of the Unitary and Collective Rationality Models: Singles, Couples, Couples with Kids and Many Adult Homes

	Single Adult	2 Adults Only	2 Adults with Others	3+ Adults
Tests of Symmetry:				
Wald Statistic from Joint Test	78.73	96.39	131.06	104.01
P-Value	0.00	0.00	0.00	0.00
Percent of Pairwise Test Rejections	16	20	6	20
Tests of Collective Rationality:				
Browning and Chiappori Linear Test				
Rank less than or equal to 2				
Wald Statistic from Joint Test	17.73	44.53	43.30	20.97
P-Value	0.66	0.00	0.00	0.46
Borderline Singular Value Test				
Rank less than or equal to 2				
P-Value	0.00	0.00	0.02	0.01
Rank less than or equal to 4				
P-Value	0.01	0.00	0.01	0.03
Konstantinides Singular Value Test				
Rank less than or equal to 2				
(α=.05,σ=.2)	0.23	0.35	0.01	0.10
(α=.01,σ=.2)	0.23	0.35	0.08	0.10
Rank less than or equal to 4				
(α=.05,σ=.2)	1.00	0.25	0.78	0.38
(α=.01,σ=.2)	1.00	0.45	0.96	0.59

Table 7: Tests of the Unitary and Collective Rationality Models: Singles and Non-Singles Facing Unpredictable Negative Shocks

	Single No Shock	Single Shock	Non-Single No Shock	Non-Single Shock
Tests of Symmetry:				
Wald Statistic from Joint Test	66.98	40.42	93.92	33.51
P-Value	0.00	0.28	0.00	0.59
Percent of Pairwise Test Rejections	16	9	7	14
Tests of Collective Rationality:				
Browning and Chiappori Linear Test				
Rank less than or equal to 2				
Wald Statistic from Joint Test	26.53	45.08	47.86	11.30
P-Value	0.19	0.00	0.00	0.96
Borderline Singular Value Test				
Rank less than or equal to 2				
P-Value	0.03	0.09	0.06	0.12
Rank less than or equal to 4				
P-Value	0.06	0.02	0.00	0.09
Konstantinides Singular Value Test				
Rank less than or equal to 2				
(α=.05,σ=.2)	0.12	0.76	0.01	0.51
(α=.01,σ=.2)	0.20	0.76	0.05	0.51
Rank less than or equal to 4				
(α=.05,σ=.2)	0.99	0.05	0.88	0.06
(α=.01,σ=.2)	1.00	0.07	0.97	0.18