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INCENTIVES AND NUTRITION FOR ROTTEN KIDS: INTRAHOUSEHOLD FOOD ALLOCATION IN THE PHILIPPINES

PIERRE DUBOIS AND ETHAN LIGON

Abstract. Using data on individual consumption expenditures from a sample of farm households in the Philippines, we construct a direct test of the risk-sharing implications of the collective household model. We are able to contrast the efficient outcomes predicted by the collective household model with the outcomes we might expect in environments in which food consumption delivers not only utils, but also nutrients which affect future productivity. Finally, we are able to contrast each of these two models with a third, involving a hidden action problem within the household; in this case, the efficient provision of incentives implies that the consumption of each household member depends on their (stochastic) productivity.

The efficiency conditions which characterize the within-household allocation of food under the collective household model are violated, as consumption shares respond to earnings shocks. If future productivity depends on current nutrition, then this can explain some but not all of the response, as it appears that the quality of current consumption depends on past earnings. This suggests that some actions taken by household members are private, giving rise to a moral hazard problem within the household.

1. Introduction

In recent years, a variety of authors have sought to test the hypothesis that intra-household allocations are efficient. Often these have been construed as tests of the "collective household" model. Special cases of this model are associated with Samuelson (1956) and Becker

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(1974); more recent formulations are associated with work by Chiappori and others (e.g. Browning and Chiappori, 1998; Chiappori, 1992). Full intra-household efficiency implies both *productive* efficiency, as well as *allocational* efficiency. Other authors who have conducted tests of intra-household efficiency have tested only one or another of these. Udry (1996), for example, focuses on productive efficiency, while a much larger number of authors have focused on allocational efficiency (e.g., Thomas, 1990; Lundberg et al., 1997; Browning and Chiappori, 1998). One important difficulty (which the previous authors each address in distinct ingenious but indirect ways) involved in testing intra-household allocational efficiency is that intra-household allocations are seldom observed—ordinarily the best an econometrician can hope for is carefully recorded data on household-level consumption. In this paper we exploit a carefully collected dataset which records expenditures for each individual within a household, and thus are able to conduct the first direct test of intra-household allocational efficiency of which we are aware.

By allocational efficiency we mean, in effect, that the marginal rate of substitution between any two commodities will be equated across household members. Importantly, we follow the Arrow-Debreu convention of indexing commodities not only by their physical characteristics, but also by the date and state in which the commodity is delivered. Thus, allocational efficiency implies not only that people within a household consume apples and oranges in the correct proportion, but also that within the household there is *full insurance*. The tests we conduct here are really a joint test of these two sorts of allocational efficiency (allocation of ordinary commodities, and allocation of state-date contingent commodities).

Without pretending any sort of exhaustive comparison of our paper with existing literature, we will briefly describe two papers, each of which shares (different) points of similarity with the present paper. Dercon and Krishnan (2000) test the hypothesis of full intra-household risk-sharing in Ethiopia by looking at the response of individual nutritional status to illness shocks. In order to deal with limitations of their data, they assume that utility depends on food consumption only via anthropometric status. So, for example, children are implicitly assumed to be indifferent between consuming a varied diet with fruit, meat, and vegetables and a subsistence diet of beans, provided that either diet results in similar weight-for-height outcomes. With this assumption, Dercon and Krishnan reject intra-household efficiency, at least for poorer households, but their results are also consistent with efficient intra-household allocation if people derive utility directly from food consumption. Our data allow us to distinguish between these possibilities, and so we allow individual utility functions to depend on consumption both directly and via the influence of consumption on nutritional outcomes. Using the same dataset as we do, Foster and Rosenzweig (1994) doesn't address the question of intra-household allocation at all, but rather asks whether or not individual anthropometric measures depend on the nature of the contract governing compensation for off-farm work, interpreting this as a test for the importance of incentives. As in Dercon and Krishnan (2000), Foster and Rosenzweig assume that food only influences utility to the extent that it influences measures of weight for height, but find that indeed incentives provided in the workplace outside the household influence consumption and physical status. In contrast to Foster and Rosenzweig, our focus is on the allocation of goods *within* the household, and on the role that food consumption may play in providing incentives above and beyond the determination of weight and height.

We proceed as follows. First, we provide an extended description of the data in Section 2. We describe some patterns observed in the sharing rules of Philippino households, including expected levels of consumption, and both individual and household-level measures of risk in both consumption and income.

Second, in Section 3 we formulate a sequence of simple models, each corresponding to a dynamic program which characterizes the problem facing the household head in different environments. The first model is a simple 'naive collective' program, in which utility depends on consumption, but productivity does not. The head allocates consumption goods, makes investment decisions, and assigns activities to other household members. From this model we derive simple restrictions on household members' intertemporal marginal rates of substitution. Working with a parametric representation of individuals' utility functions, we exploit these restrictions to estimate a vector of preference parameters, which allows us to characterize changes in intra-household sharing rules as a function of observable individual characteristics such as age and sex.

Our second model generalizes the first, in that we allow for the possibility that food consumption may influence future productivity. In particular, while food consumption produces both direct utility (which depends on the quantity and quality of different kinds of foodstuffs), and also represents a sort of human capital investment which influences labor productivity (but this investment depends only on the quantity and nutritional content of foodstuffs, and *not* food quality). This leads us to consider a model of nutritional investments, which reproduces some of the features of models formulated by, e.g., **??**. In this model there is no private information and hence no need to provide incentives, but the head takes into account the effects that consumption has on both utility and productivity. This model also implies a set of restrictions on household members' intertemporal marginal rates of substitution which distinguish it from the 'naive collective' model. A key testable prediction of this model which distinguishes it from the naive collective model is that if there's an anticipated increase in the marginal product of labor for household member i, then nutritional investment in this member will increase at the same time that the quality of food consumed by i decreases.

Finally, our third model extends the model with nutritional investment so that the off-farm labor effort of other household members isn't necessarily observed by the household head.[1] Accordingly, the intra-household sharing rule must be incentive compatible. The key difference between this model and the naive collective model or the nutritional investment model is that household members must be provided with appropriate incentives to induce them to take the actions recommended by the household head. We show that in this model of efficient intra-household incentives food quality should respond to unpredicted individual earnings shocks. Section 5 concludes.

2. The Data

The main data used in this paper are drawn from a survey conducted by the International Food Policy Research Institute and the Research Institute for Mindanao Culture in the Southern region of the Bukidnon Province of Mindanao Island in the Philippines during 1984–1985. These data are described in greater detail by Bouis and Haddad (1990) and in the references contained therein. Additional data on weather used in this paper were collected by the first author from the weather station of Malay-Balay in Bukidnon.

Bukidnon is a poor rural and mainly agricultural area of the Philippines. Early in 1984, a random sample of 2039 households was drawn from 18 villages in the area of interest. A preliminary survey was administered to each household to elicit information used to develop criteria for a stratified random sample later selected for more detailed study. The preliminary survey indicated that farms larger than 15

[1]"Off-farm labor" in this context means agricultural work on somebody else's farm. Using the same dataset, Foster and Rosenzweig (1994) find evidence which suggests that the managers of such workers can't observe labor effort, so that presumably the geographical remote household head can't observe this effort either.

	Expend.	Rice	Corn	Staples	Meat	Veg.	Snacks	Calories	Protein
Sample	5.914	0.724	1.203	0.3	1.876	0.477	0.809	1823.626	54.664
Male	6.428	0.802	1.271	0.295	1.984	0.484	1.068	1926.152	57.508
Female	5.361	0.64	1.13	0.306	1.76	0.47	0.53	1713.438	51.606
$\leq$ 5 years	3.802	0.398	0.727	0.226	1.407	0.241	0.386	1137.078	34.886
6–10 years	4.792	0.607	1.044	0.276	1.629	0.362	0.422	1603.433	48.102
11–15 years	6.878	0.872	1.51	0.37	2.239	0.62	0.632	2232.415	66.056
16–25 years	7.929	1.061	1.606	0.362	2.271	0.758	1.238	2412.472	71.975
26–50 years	8.879	1.009	1.612	0.359	2.491	0.693	2.074	2416.091	72.495
$>$ 50 years	7.119	0.877	1.44	0.247	1.875	0.567	1.363	2136.464	61.653
$\leq$ 5 years (Male)	3.719	0.419	0.733	0.23	1.405	0.216	0.293	1166.963	35.476
6–10 years (Male)	4.943	0.671	1.04	0.269	1.712	0.366	0.444	1638.98	48.926
11–15 years (Male)	7.107	0.924	1.669	0.379	2.279	0.582	0.719	2360.029	69.036
16–25 years (Male)	9.465	1.21	1.828	0.355	2.623	0.837	1.956	2688.411	80.574
26–50 years (Male)	10.411	1.18	1.769	0.348	2.69	0.74	3.007	2653.379	79.364
$>$ 50 years (Male)	7.96	1.039	1.497	0.229	1.944	0.626	1.732	2300.727	66.907
$\leq$ 5 years (Female)	3.901	0.372	0.72	0.221	1.409	0.272	0.497	1101.531	34.184
6–10 years (Female)	4.638	0.54	1.048	0.283	1.544	0.357	0.399	1566.915	47.256
11–15 years (Female)	6.657	0.822	1.357	0.362	2.201	0.657	0.549	2109.172	63.179
16–25 years (Female)	6.614	0.934	1.415	0.367	1.97	0.69	0.623	2176.366	64.617
26–50 years (Female)	6.858	0.783	1.406	0.374	2.228	0.63	0.844	2102.985	63.43
$>$ 50 years (Female)	4.573	0.39	1.269	0.302	1.667	0.391	0.248	1639.464	45.756

TABLE 1. Mean Daily Food Consumption. The first column reports mean total food expenditures per person (in constant Philippine pesos). The next six columns report means for particular sorts of food expenditures (differences between total food expenditures and the sum of its constituents is accounted for by "other non-staple" foods). The final two columns report individual calories and protein derived from individual-level food consumption.

hectares amounted to less than 3 per cent of all households, a figure corresponding closely to the 1980 agricultural census. Only households farming less than 15 hectares and having at least one child under five years old were eligible for selection. Based on this preliminary survey, a stratified random sample of 510 households from ten villages was chosen. Some attrition (mostly because of outmigration) occurred during the study and a total of 448 households from ten villages finally participated in the four surveys conducted at four month intervals beginning in July 1984 and ending in August 1985. The total number of persons in the survey is 3294.

The nutritional component of the survey interviewed respondents to elicit a 24-hour recall of individual food intakes, as well as one month and four month interviews to measure household level food and non-food expenditures. Food intakes include quantity information for a highly disaggregated set of food items. Individual food expenditures can be computed using direct information on the prices and quantities of foods purchased, and on quantities consumed out of own-production and in-kind transactions.

Later in the paper we will concern ourselves with changes in individuals' shares of consumption, intentionally neglecting to explain differences in *levels* of consumption, where theory has less to say. However, some of these differences are interesting, and so some information on levels of individual expenditures along with caloric and protein intakes are given in Table 1. Turning to the final columns of the table, we first note that the average individual in our sample is not terribly well-fed. Comparing the figures in Table 1 to standard guidelines for energy-protein requirements (WHO, 1985) reveals that even the average person in our sample faces something of an energy deficit.

When we consider the average consumption of different age-sex groups, it becomes clear that particular groups are particularly malnourished. Also, these figures show clearly that the relationship between consumptions and age follows consistently an inverse U shaped pattern which is quite reassuring about the reliability of these measures.

The picture of inequality drawn by our attention to energy and protein intakes is, if anything, exacerbated by closer attention to the sources of nutrition. While all of the foods considered here are sources of calories and protein, it also seems likely that food consumption is valued not *just* for its nutritive content, but that individuals also derive some direct utility from certain kinds of consumption. This point receives some striking support from Table 1. Consider, for example, average daily expenditures by males aged 26–50, compared with the same category of expenditures by women of the same age. The value of expenditures on male consumption of all staples is 28 per cent greater than that of females of the same age. This difference seems small enough that it could easily be attributed to differences in activity or metabolic rate. However, compare expenditures on what are presumably superior goods: expenditures on male consumption of meat (and fish), vegetables, snacks (including fruit) is 424 per cent greater than the corresponding expenditures by women in the same age group. Since nothing like a difference of this size shows up in calories or protein, this seems like very strong evidence that intra-household allocation mechanisms are designed to put a particularly high weight on the *utility* of prime-age males relative to other household members, quite independent of those prime-age males' greater energy-protein requirements. Note that although these differences in consumption seem to point to an inegalitarian allocation, these differences provide no evidence to suggest that household allocations are inefficient.

3. Some Simple Models

Consider a household having n members, indexed by $i = 1, 2, \ldots n$, where an index of 1 is understood to refer to the household head. Time is indexed by $t = 0, 1, 2, \ldots$. During each period, member i consumes a K-vector of nutrients $c_{it} = (c_{it}^1, ..., c_{it}^K)^\mathsf{T}$. These nutrients have corresponding qualities $\varphi_{it} = (\varphi_{it}^1, ..., \varphi_{it}^K)^\mathsf{T} \in [0, \infty)$ where each element φ_{it}^k is assumed to be non-negative. At the same time, i supplies some labor a_{it}.

Household member i derives direct utility from both the quantity and quality of his consumption and disutility from his labor. Further, at time t person i possesses a set of characteristics (e.g., sex, health, age) which, for short, we denote by the vector b_{it}. These characteristics may have an influence on the utility he derives from both consumption and activities. Thus, we write his momentary utility at t as some $U(\varphi_{it}, c_{it}, b_{it}) + Z_i(a_{it}, b_{it})$, where the function U is assumed to be increasing, concave, and continuously differentiable in each of the nutrients and in each of the qualities, and Z_i is the (dis)utility of labor a_{it} for an individual with characteristics b_{it}. Future utility is discounted via a common discount factor $\beta \in (0, 1)$.

3.1. **Stochastic Structure.**

Households face two basic sources of uncertainty. First, in each period t an index of some public shock $\theta_t \in \Theta = \{1, 2, \ldots, S\}$ is realized; among other things, the realization of θ_t

determines the prices faced by the household. Note that while publicly observed, this shock need not be common, including e.g., information on expected wages for different individuals. The probability of some particular θ' occurring at time t may depend on the previous period's realization θ_{t-1} via a collection of Markovian transition probabilities $\Pr(\theta_t|\theta_{t-1})$, while the cumulative probability that the realization of θ_t will be less than or equal to some value θ' is written $G(\theta'|\theta) = \sum_{r=1}^{\theta'} \Pr(r|\theta)$.

The second source of uncertainty faced by households is production uncertainty. Each period t, each household member $i = 1, \ldots, n$ supplies labor a_{it}, and produces some quantity of the numeraire good $y_{it} \in \mathbb{R}$ at t. Each of these outputs is drawn from a continuous distribution $F^i(y_i|a, z, \theta')$ which depends on the labor a and investment z supplied and on the public shock θ'. We assume that for every (a, z, θ') the corresponding density $f^i(y_i|a, z, \theta')$ exists, and that the support of y_i doesn't vary with a. We further assume that f^i is a continuously differentiable function of a, and denote such derivatives by $f^i_a(y_i|a, z, \theta')$.

As the notation is meant to suggest, output y_{it} is assumed to be conditionally independent of y_{js} for all $(i, t) \neq (j, s)$. Accordingly, using bold characters to denote lists of variables for each family member, let $\boldsymbol{y} = (y_1, y_2, \ldots, y_n)$ denote the list of outputs for each member of the family, with joint distribution $F(\boldsymbol{y}|\boldsymbol{a}, \boldsymbol{z}, \theta') = \prod_{i=1}^n F^i(y_i|a_i, z_i, \theta')$ and joint density $f(\boldsymbol{y}|\boldsymbol{a}, \boldsymbol{z}, \theta')$. Denote by ω the collection of random elements which affect household i at the end of a period, so that $\omega = (\boldsymbol{y}, \theta')$; for brevity, let $H(\omega|\boldsymbol{a}, \boldsymbol{z}, \theta) = F(\boldsymbol{y}|\boldsymbol{a}, \boldsymbol{z}, \theta')G(\theta'|\theta)$.

The individual characteristics of an individual are allowed to evolve over time. In particular, let M be a law of motion for individual characteristics, with $b_{it+1} = M(b_{it}, c_{it}, \theta_t)$. Similarly, let $\mathbf{b}_t$ denote the list of individual characteristics at t, with $\mathbf{M}$ the law of motion for characteristics for all n family members. The idea here is that e.g., person i's weight at $t + 1$ may depend on his weight in the previous period as well as on his consumption. Note that the evolution of b_{it} is assumed *not* to depend on the quality of consumption; only on its quantities. We'll think of the vector of consumptions c as a bundle of nutrients. A variety of different diets could plausibly provide the same nutrient bundle c; however, not all of these diets will provide the same level of utility.

3.2. **The Household Head's Problem.** The household head decides the labor each household member should supply, how much the household should collectively save or invest, how to allocate the remaining household resources across household members, and what resources should be promised to individual family members in the future.[2] We formulate the problem as a dynamic program, adopting an approach similar to e.g., Spear and Srivastava (1987) in which future 'utility promises' are made by the head to individual family members and appear as state variables in the head's dynamic programming problem.

The head chooses the allocation of consumption only after observing the realization of ω, so that consumptions are assigned after individual outputs are determined and the public shock θ' is observed. Allocating consumption involves choosing both a vector of nutrients $c_i(\omega)$ to award to person i in state ω as well as corresponding qualities $\varphi_i(\omega)$.

The implicit price of nutrient k may depend on its quality and the public shock;[3] then the price of nutrient k with quality φ^k when the public shock is θ' is denoted $p^k(\varphi^k, \theta')$. By assumption this function takes the form

$$p^k(\varphi^k, \theta') = p^{k,0}(\theta')(\underline{\phi}^k + \varphi^k)^{1+\rho_k},$$

where $p^{k,0}(\theta')$ captures the influence of the public shock on prices for nutrient k, and $\underline{\phi}^k$may be thought of as a lower bound on the available qualities. Thus $(\underline{\phi}^k + \varphi^k)^{1+\rho_k}$ captures the role played by quality in determining price, where ρ_k is a nutrient-specific parameter that reflects the elasticity of price with respect to quality. Let $p(\varphi, \theta')$ denote the row vector-valued function $(p^1(\varphi^1, \theta'), p^2(\varphi^2, \theta'), \ldots, p^K(\varphi^K, \theta'))$, with elements corresponding to different nutrients. Accordingly, if in period t the public shock was θ_t and the household had net savings s, then for any time $t+1$ realization of ω the head must satisfy the budget constraint

$$(1) \qquad \sum_{i=1}^{n} p(\varphi_{i,t+1}(\omega_{t+1}), \theta_{t+1}) c_{i,t+1}(\omega_{t+1}) \leq \sum_{i=1}^{n} y_{i,t+1} - \sum_{i=1}^{n} z_{i,t+1}(\omega_t).$$

At the same time that the head allocates contemporaneous consumption, she also makes promises to other household members about their

[2]There is a small literature devoted to the subject of division of responsibilities between adult males and females in Philippine households (**?**). Though unfortunately we can't offer independent evidence from our dataset, this list of tasks seems to be consistent with the kinds of responsibilities typically undertaken by adult females, rather than males. Accordingly, we assume below that the senior female in the household is the household head unless noted otherwise.

[3]Throughout we deal with implicit prices for nutrients, rather than the observed prices for the actual food which yields the nutrients. To relate these, let there be L possible kinds of food with quality-adjusted prices $q(\varphi)$, and let Π denote a $K \times L$ "food conversion matrix" such that for any L-vector of food quantities x, $c = \Pi x$. Now, let Π^+ be a generalized inverse of Π; then the implicit price $p(\varphi)$ of nutrients c will be $q^\mathsf{T}\Pi^+$.

future levels of (discounted, expected) utility. Past promises must also be honored. Thus, if the head promised future utils w_{it} to person i at date $t-1$, then honoring that promise requires that

$$\int [U(\varphi_{i,t}(\omega_t), c_{i,t}(\omega_t), b_{it}) + Z_i(a_{it}, b_{it}) + \beta w_{i,t+1}(\omega_t)] dH(\omega_t | \boldsymbol{a}_t, \theta_t) = w_{it}. \tag{2}$$

We formulate the problem facing the head recursively. At the beginning of a period, the head takes as given an n-vector reflecting her current utility promises to other household members ($\boldsymbol{w}$), investments from the previous period ($\boldsymbol{z}$), a list of the characteristics of household members ($\boldsymbol{b}$), and the previous period's public shock θ. Given her preferences, the head then assigns labor, decides how much to save/invest for subsequent periods, and makes another set of utility promises, all subject to the constraints implied by these prices and resources. In particular, let $V(\boldsymbol{w}, \boldsymbol{z}, \boldsymbol{b}, \theta)$ denote the discounted, expected utility of the head given the current state, and let this function satisfy

Program 1.

$$\begin{aligned} V(\boldsymbol{w}, \boldsymbol{z}, \boldsymbol{b}, \theta) = \max_{\{a_i, z_i', \{\varphi_i(\omega), c_i(\omega), w_i'(\omega)\}_{\omega \in \Omega}\}_{i=1}^n} \int & [U(\varphi_1(\omega), c_1(\omega), b_1) + Z_1(a_1, b_1) \\ & + \beta V\left(\boldsymbol{w}'(\omega), \boldsymbol{z}', \boldsymbol{M}(\boldsymbol{b}, \boldsymbol{c}(\omega), \theta')\right)] \, dH(\omega | \boldsymbol{a}, \boldsymbol{z}, \theta) \end{aligned} \tag{3}$$

subject to the household budget constraint

$$\sum_{i=1}^n p(\varphi_i(\omega), \theta')^\top c_i(\omega) \leq \sum_{i=1}^n y_i - \sum_{i=1}^n z_i' \tag{4}$$

for all $\omega = (\boldsymbol{y}, \theta') \in \Omega$; and subject also to a set of promise-keeping constraints

$$\int [U(\varphi_i(\omega), c_i(\omega), b_i) + Z_i(a_i, b_i) + \beta w_i(\omega)] dH(\omega | \boldsymbol{a}, \boldsymbol{z}, \theta) = w_i, \tag{5}$$

for all $i = 1, \ldots, n$; and subject finally to the requirement $\varphi_i^k(\omega) \geq 0$ for all $i = 1, \ldots, n$; all nutrients $k = 1, \ldots, K$; and all states $\omega \in \Omega$.

In this recursive formulation of the problem we're able to drop the time subscripts from variables: all variables may be assumed to be dated t unless adorned by the notation $'$, in which case these are dated $t+1$.

Lemma 1. *Let $\alpha_{i,t} = \frac{\partial V}{\partial w_i}(\boldsymbol{w}_t, \boldsymbol{z}_t, \boldsymbol{b}_t, \theta_t)$ in Program 1. If $U(x, b)$ is a concave function of x for all b, then $\alpha_{i,t} = \alpha_{i,t+1}$ for all dates t.*

Proof. The envelope condition with respect to w_i in Program 1 implies that $\frac{\partial V}{\partial w_i}(\boldsymbol{w}_t, \boldsymbol{z}_t, \boldsymbol{b}_t, \theta_t) \equiv \alpha_{it}$ is equal to the Lagrange multiplier on the promise-keeping constraint (5). This fact along with the first order condition for the head's problem with respect to $w_i(\omega_{t+1})$ then imply that $\alpha_{i,t} = \alpha_{i,t+1}$. The concavity of U is a sufficient condition for this first order condition to characterize the solution to the head's problem. □

The lemma simply reflects the point that in environments such as that described here, optimal allocations of consumption will keep the ratio of marginal utilities of different household members constant across both dates and states; this is basically a consequence of risk aversion and our assumption of time separable expected utility.

We want to consider the outcomes predicted by this simple model under a variety of different assumptions regarding preferences and other aspects of the environment facing the household. We begin by assuming a particular parametric form for the utility function U, adopting

Assumption 1. *We place the following three restrictions on the form of the utility function:*

(1) $U(\varphi, c, b) = \sum_{k=1}^{K} U_k(\varphi^k c^k, b)$;
(2) $U_k(\varphi^k c^k, b) = h_k(b)\frac{(\varphi^k c^k)^{1-\gamma_{ik}}}{1-\gamma_{ik}}$; *and*
(3) $\log h_k(b)$ *is a linear function of the vector* b *for all* $k = 1, \ldots, K$.

In addition, we'll find it convenient to think of there being three different sorts of individual characteristics. Accordingly, we partition the vector of personal characteristics b_{it} into three distinct parts. Let υ_i denote time invariant characteristics of person i (such as sex), which may or may not be observed by the econometrician. Let ζ_{it} denote observed time-varying characteristics of the same person (such as age and health). In contrast, let ξ_{it} denote time-varying characteristics of person i at time t which aren't observed in the data. Then without additional loss of generality, let $(\iota_k^1, \delta_k, \iota_k^3)$ be a triple of vectors which select and weight characteristics which influence the utility of consumption of nutrient k such that $\log h_k(b_{it}) = \iota_k^{1\top}\upsilon_i + \delta_k^{\top}\zeta_{it} + \iota_k^{3\top}\xi_{it}$, or more compactly $\log h_k(b_{it}) = \upsilon_i^k + \delta_k^{\top}\zeta_{it} + \xi_{it}^k$.

We now turn our attention to characterizing the relationship between consumption, expenditures, and quality for various household members relative to the household head, under a variety of alternative assumptions. These are summarized by

Proposition 1. *If preferences satisfy Assumption 1 then the consumption allocations which solve Program 1 will satisfy*

$$\Delta \log c^k_{it} = \frac{\gamma_{1k}}{\gamma_{ik}} \Delta \log c^k_{1t} + \frac{\delta'}{\gamma_{ik}} (\Delta\zeta_{it} - \Delta\zeta_{1t}) + \frac{1}{\gamma_{ik}} (\Delta\xi_{it} - \Delta\xi_{1t}) + \frac{\rho_k}{\gamma_{ik}} \left(\Delta \log(\underline{\phi}^k + \varphi^k_{1t}) - \Delta \log(\underline{\phi}^k + \varphi^k_{it})\right) \tag{6}$$

for all $k = 1, \ldots, K$, $i = 1, \ldots, n$, *and all dates* t.

Proof. Let $\alpha_{i\tau}$ denote the Lagrange multiplier associated with the promise-keeping constraint (5) in the present period, denoted τ. Then the first order conditions from the head's problem for φ^k_i and φ^k_1 and the parameterization of utility assumed in Assumption 1 imply that

$$\alpha_{it} c_{it}^{-\gamma_{ik}} h_k(b_{it}) = \left(\frac{\underline{\phi}^k + \varphi^k_{it}}{\underline{\phi}^k + \varphi^k_{1t}}\right)^{\rho_k} c_{1t}^{-\gamma_{1k}} h_k(b_{1t})$$

for $t = \tau$ and $t = \tau - 1$. Taking logarithms of both sides, subtracting the expression evaluated at $\tau - 1$ from the expression evaluated at τ, and rearranging terms yields

$$\Delta \log(\alpha_{it}) + \Delta \log c^k_{it} = \frac{\gamma_{1k}}{\gamma_{ik}} \Delta \log c^k_{1t} + \frac{\delta'}{\gamma_{ik}} (\Delta\zeta_{it} - \Delta\zeta_{1t}) + \frac{1}{\gamma_{ik}} (\Delta\xi_{it} - \Delta\xi_{1t}) + \frac{\rho_k}{\gamma_{ik}} \left(\Delta \log(\underline{\phi}^k + \varphi^k_{1t}) - \Delta \log(\underline{\phi}^k + \varphi^k_{it})\right),$$

where the Δ is the linear difference (over t) operator. Exploiting the lemma yields (6). □

Now consider the case in which there's no nutritional investment (food consumption doesn't influence future characteristics). Then

Proposition 2. *If preferences satisfy Assumption 1 and* $M(b, c, \theta') = M(b, \hat{c}, \theta')$ *for all* (b, θ') *and all* $c, \hat{c} \in \mathbb{R}^k$, *then the consumption allocations which solve Program 1 will satisfy*

$$\Delta \log c^k_{it} = \frac{\gamma_{1k}}{\gamma_{ik}} \Delta \log c^k_{1t} + \frac{\delta'}{\gamma_{ik}} (\Delta\zeta_{it} - \Delta\zeta_{1t}) + \frac{1}{\gamma_{ik}} (\Delta\xi_{it} - \Delta\xi_{1t}) \tag{7}$$

for all $k = 1, \ldots, K$, $i = 1, \ldots, n$, *and all dates* t. *Further, letting* p^k_t *denote the common price paid for consumption of nutrient* k *in period* t

for all household members, expenditures for the kth nutrient will satisfy

$$(8)\quad \Delta \log p_t^k c_{it}^k = \frac{\gamma_{1k}}{\gamma_{ik}} \Delta \log p_t^k c_{1t}^k + \frac{\delta'}{\gamma_{ik}} (\Delta\zeta_{it} - \Delta\zeta_{1t}) + \left(1 - \frac{\gamma_{1k}}{\gamma_{ik}}\right) \Delta \log p_t^k + \frac{1}{\gamma_{ik}} (\Delta\xi_{it} - \Delta\xi_{1t})$$

for all $k = 1, \dots, K$, $i = 1, \dots, n$, and all dates t.

Proof. This is a special case of the more general Proposition **??** *infra.* □

We next turn our attention to characterizing within-household consumption allocations when the labor of members can't be directly observed by the household head. In this situation, the problem facing the head can be expressed as

Program 2.

$$(9)\quad V(\boldsymbol{w}, \boldsymbol{z}, \boldsymbol{b}, \theta) = \max_{\{a_i, z_i', \{\varphi_i(\omega), c_i(\omega), w_i'(\omega)\}_{\omega\in\Omega}\}_{i=1}^n} \int [U(\varphi_1(\omega), c_1(\omega), b_1) + Z_1(a_1, b_1) + \beta V(\boldsymbol{w}'(\omega), \boldsymbol{z}', \boldsymbol{M}(b, \boldsymbol{c}(\omega), \theta'))] \, dH(\omega|\boldsymbol{a}, \boldsymbol{z}, \theta)$$

subject to the household budget constraint (4) for all $\omega = (\boldsymbol{y}, \theta') \in \Omega$; and subject also to the set of promise-keeping constraints (5). In addition, the household head must choose allocations and labor assignments which satisfy a set of incentive compatibility constraints

$$(10)\quad a_i \in \operatorname*{argmax}_a \int [U(\varphi_i(\omega), c_i(\omega), b_i) + Z_i(a, b_i) + \beta w_i(\omega)] \cdot d\left(F^i(y_i|a, z_i, \theta') \prod_{j\neq i} F^j(y_j|a_j, z_j\theta') G(\theta'|\theta)\right)$$

for all $i = 1, \dots, n$; and subject finally to a requirement that $\varphi_i^k(\omega) \in \Phi$ for all $i = 1, \dots, n$; all nutrients $k = 1, \dots, K$; and all states $\omega \in \Omega$.

Program 2 is identical to Program 1 save for the addition of the incentive compatibility constraint (10), which requires that person i will have no incentive to deviate from the action a_i recommended by the head. Unfortunately, it's difficult to characterize the effects of this kind of hidden action when the requirement of incentive compatibility is expressed in the form of (10). Accordingly, we also provide an alternative program, which will have the same solutions so long as the so-called 'first order approach' is valid.

Program 3.

$$V(\boldsymbol{w},\boldsymbol{z},\boldsymbol{b},\theta) = \max_{\{a_i,z_i',\{\varphi_i(\omega),c_i(\omega),w_i'(\omega)\}_{\omega\in\Omega}\}_{i=1}^n} \int [U(\varphi_1(\omega),c_1(\omega),b_1) + Z_1(a_1,b_1) + \beta V(\boldsymbol{w}'(\omega),\boldsymbol{z}',\boldsymbol{M}(\boldsymbol{b},\boldsymbol{c}(\omega),\theta'))]\, dH(\omega|\boldsymbol{a},\boldsymbol{z},\theta) \tag{11}$$

subject to the household budget constraint (4) for all $\omega = (\boldsymbol{y},\theta') \in \Omega$*; and subject also to the set of promise-keeping constraints (5). In addition, the household head must choose allocations and labor assignments which satisfy the first-order conditions from the agent's choice of labor,*

$$\int [U(\varphi_i(\omega),c_i(\omega),b_i) + Z_i(a,b_i) + \beta w_i(\omega)] \frac{f_a^i(y_i|a_i,z_i\theta')}{f^i(y_i|a_i,\theta')} \cdot d\left(F(\boldsymbol{y}|\boldsymbol{a},\boldsymbol{z},\theta')G(\theta'|\theta)\right) = -\frac{\partial Z_i(a_i,b_i)}{\partial a_i} \tag{12}$$

for all $i = 1,\ldots,n$*; and subject finally to a requirement that* $\varphi_i^k(\omega) \in \Phi$ *for all* $i = 1,\ldots,n$*; all nutrients* $k = 1,\ldots,K$*; and all states* $\omega \in \Omega$*.*

4. Empirical Tests

We've presented three distinct models of intra-household allocation. Each of these models can be characterized by positing a different rule governing the evolution of the share parameters $\{\alpha_t^i\}$. The first model is a simple version of the collective household model, in which food consumption is allocated to different household members in order to produce utility; the weight of each members' utility depends on the utility promises made by the head to that member. In this model, changes in a member's share of consumption (allowing for age-sex specific mappings from consumption to utility) are due only to *unpredictable* changes in the altruism of the head.

The second model (nutritional investment) is one in which the allocation of food affects not only the utility of different household members, but also the production possibility set of the household. In this model, the allocation of energy and protein in the household may respond not only to unpredictable changes in the head's altruism, but may also vary because the productivity of particular household members may depend on the consumption assignment in a way which varies over time. The most obvious example might have to do with the additional energy required by some household members during different seasons: household members who engage in heavy agricultural labor may be assigned a disproportionate share of calories during the harvest season, for example, or these same people may receive a greater share of protein in advance of a period of hard labor.

The third model (intra-household moral hazard) is one in which food is allocated in such a way as to provide incentives to particular household members. Equivalently, we can think of the household head feeling more altruism toward people in the household who are unexpectedly productive. These incentives may partially overcome the problem of moral hazard associated with unobserved actions taken by the household member. In this model, a particularly productive household member is rewarded with a larger share of household resources, because this observed high productivity allows the inference that the productive household member probably worked particularly hard. Importantly, it's *surprises* in a member's production that are important in this story: if a household member always works hard and is always productive, then this won't produce any *changes* in the expected share of household resources assigned to that household member.

4.1. **Estimating the Unitary Household Model.** Per Proposition 1, equation (6) gives a relationship between the growth rate of consumption and expenditures for the household head and that of each household member if preferences satisfy Assumption 1 and if intra-household allocations are efficient. Recall that while shares of consumption and expenditures depend on total household expenditures and individual characteristics, they should *not* depend on the realization of any idiosyncratic shock unless that shock directly influences preferences. Note that this restriction does not directly bear on changes in a member's share of total household resources—the expression for such a share depends on the preferences of every household member. Rather, we characterize only the changes in the growth rate of expenditures and consumption relative to the household head. To reiterate, if the unitary household model is correct, the disturbances in (6) will be unrelated to individual-specific outcomes, such as off-farm labor income or changes in the composition of household income. This can be tested by introducing overidentifying variables in the regression implied by (6).

It may be worth dwelling on the interpretation of (6). Note that there's no prediction regarding the *level* of a member's share; only a prediction about what produces changes in that share. Thus, this equation is of no use in trying to understand inequality in the allocation of household resources; only in understanding changes in the way in which those resources are shared. One feature of the environment which may help to explain changes in household shares has to do with heterogenous risk preferences: if household member i is more risk averse than the household head, then changes in total household resources will produce smaller percentage changes in i's consumption than it will in the consumption of the head (and conversely). Changes of this sort will be captured by our estimates of θ_k, which enter the first term on the right-hand-side of equation (**??**). Alternatively, changes in the relative needs of different household members may result in changes in shares of food expenditures and nutrition. For example, as a small boy matures into a grown man, one would expect that person's share of household resources to increase, basically as a consequence of changes in the utility that person derives from food consumption. Changes of this sort are captured by changes in ζ_{it}, and depend on the vector of parameters δ.

Our first attempts to estimate (6) are reported in Table 2. Here we exploit the relationship between ratios of direct and indirect utility given by (**??**) and (**??**) to estimate a system of three equations, each of the form of (6), but with different measures of consumption.

Our first measure of consumption is individual food expenditures; our second is individual caloric intake; and our third is total protein intake. For time-varying individual characteristics ζ_{it}, we've simply used the logarithm of age and a time effect. For the fixed individual characteristics υ_i governing relative risk aversion ($\theta_k'\upsilon_i$), we've simply used gender. Since residuals from these three different equations are *a priori* related, we've used a three-stage least squares procedure to estimate this system of seemingly unrelated regressions.

In the first stage, we use data on changes in log household-level food expenditures (collected via a different survey instrument than our data on individual-level consumption) to instrument for changes in the log of the household heads' consumption. In the second stage we use these first stage results to estimate each equation separately, and then use estimated residuals from this stage to construct estimates of the covariance matrix of residuals across equations. The third stage uses this estimated covariance matrix to compute more efficient point estimates and consistent estimates of the standard errors of the estimated coefficients (details may be found in Appendix **??**).

Table 2 shows the results of the base nutrient instrumental variables regressions (that is, the regressions for individual food expenditures, calories intakes and protein intakes). The results show that individual shares of food expenditures increase by about 78% as much as that of the household head (79% if the head individual is a male, 77% if a female and 78% if the spouse). For calories, these shares are of 61%

	Food Expend.	Calories	Protein	F (p-value)	Food Expend.	Calories	Protein	F (p-value)
$\frac{\theta' v_1}{\theta' v_i}$: Male	0.7919*	0.6098*	0.8017*	1282.0314	0.7906*	0.6158*	0.8060*	1264.3965
	(0.0155)	(0.0128)	(0.0127)	(0.0000)	(0.0156)	(0.0130)	(0.0128)	(0.0000)
$\frac{\theta' v_1}{\theta' v_i}$: Female	0.7807*	0.6297*	0.8337*	2025.5254	0.7804*	0.6316*	0.8358*	2013.5378
	(0.0124)	(0.0114)	(0.0110)	(0.0000)	(0.0124)	(0.0114)	(0.0111)	(0.0000)
$\frac{\delta}{\theta' v_i}$: Age male	0.2705*	0.5079*	0.5243*	5.3196	0.2693*	0.5122*	0.5301*	5.4399
	(0.1154)	(0.1857)	(0.1539)	(0.0012)	(0.1162)	(0.1879)	(0.1554)	(0.0010)
$\frac{\delta}{\theta' v_i}$: Age female	0.0014	0.1787	0.1257	0.5021	0.0022	0.1809	0.1299	0.5027
	(0.1311)	(0.2109)	(0.1749)	(0.6808)	(0.1311)	(0.2121)	(0.1754)	(0.6804)
Days sick, male	−0.0162*	−0.0046	−0.0082	13.9618	−0.0161*	−0.0044	−0.0080	13.8521
	(0.0033)	(0.0053)	(0.0044)	(0.0000)	(0.0033)	(0.0053)	(0.0044)	(0.0000)
Days sick, female	−0.0060*	0.0007	−0.0023	4.2133	−0.0059*	0.0008	−0.0022	4.1361
	(0.0029)	(0.0046)	(0.0039)	(0.0055)	(0.0029)	(0.0047)	(0.0039)	(0.0061)
Pregnant	−0.0986	−0.2274	−0.1843	0.9625	−0.0993	−0.2307	−0.1871	0.9826
	(0.0835)	(0.1343)	(0.1114)	(0.4093)	(0.0833)	(0.1349)	(0.1115)	(0.3998)
Nursing	0.0093	0.0092	0.0105	0.3325	0.0104	0.0106	0.0118	0.4021
	(0.0112)	(0.0181)	(0.0150)	(0.8019)	(0.0112)	(0.0182)	(0.0150)	(0.7515)
Second quarter	0.1005*	0.1159*	0.1273*	16.6169	0.0845*	0.0953*	0.1058*	11.2981
	(0.0176)	(0.0279)	(0.0232)	(0.0000)	(0.0181)	(0.0289)	(0.0239)	(0.0000)
Third quarter	0.0666*	0.0627*	0.0450	6.5953	0.0834*	0.0853*	0.0661*	7.8079
	(0.0176)	(0.0283)	(0.0235)	(0.0002)	(0.0187)	(0.0303)	(0.0250)	(0.0000)
Fourth quarter	−0.0487*	−0.0297	0.0101	19.0978	−0.0679*	−0.0552	−0.0126	14.8076
	(0.0177)	(0.0282)	(0.0234)	(0.0000)	(0.0208)	(0.0335)	(0.0277)	(0.0000)
y^p_{1t+1}	—	—	—	—	−0.4372*	−0.5932*	−0.5659*	3.2334
	—	—	—	—	(0.1524)	(0.2466)	(0.2039)	(0.0213)
y^u_{1t+1}	—	—	—	—	−0.0018	−0.0147	−0.0150	0.3808
	—	—	—	—	(0.0162)	(0.0262)	(0.0216)	(0.7669)
y^p_{it+1}	—	—	—	—	0.1178	0.1395	0.0670	0.1655
	—	—	—	—	(0.2880)	(0.4655)	(0.3849)	(0.9197)
y^u_{it+1}	—	—	—	—	0.0640*	0.0945*	0.0915*	2.2131
	—	—	—	—	(0.0291)	(0.0471)	(0.0389)	(0.0844)

TABLE 2. Expenditure & nutritional intakes within the household. Point estimates may be interpreted as changes in person i's share of household food expenditures/calories/protein relative to the share of the household head. Figures in parentheses are standard errors.

for males, 74% for females and 49% for spouse. In the case of protein, it is 80% for males, 92% for females and 71% for spouse. Thus, while food expenditures shares do not change differently as a function of the head's changes across members of the rest household (that is, they do not differ between spouse and other members of the household or between gender), we do not find the same evidence on calories and protein intakes. Actually, for calories and proteins, the head's spouse shares a smaller part of calories increases than other male members who share a smaller part than other female members. This means that household members' preferences differ between the household head and others.

First, one measure of household sharing is given by the coefficients associated with the household heads' consumption growth. If all household members had homogeneous risk attitudes, then these coefficients would be equal to one under the null hypothesis of perfect risk-sharing. In fact, these coefficients are all much less than one, ranging from 0.61 for male sharing of calories to 0.83 for female sharing of protein. On a strict interpretation of (6) this implies that household heads are less averse to risk than are other household members, and bear a disproportionate amount of the aggregate risk faced by the household. Further, the head's tolerance of variation in the consumption of protein (relative to other household members) is greater than is his relative tolerance of variation in food expenditures, suggesting that when the household faces an adverse shock, the rest of the family substitutes toward less expensive sources of calories to a greater extent than does the head. For protein the reverse is true with female members of the household, except for the spouse.

In contrast to results for risk attitudes, maturity has a very different influence on consumption shares across sexes. In particular, on average a one percent increase in the ratio of a male's age to head's age results in a 0.27 per cent increase in the value of food consumed by that male, a corresponding 0.51 per cent increase in calories and a 0.52 per cent increase in protein intake. As for females, a one percent increase in the ratio of a female's age to head's age results in an almost zero change in the value of food consumed by that female, a corresponding (insignificant) 0.18 per cent increase in calories and an (insignificant) 0.13 in protein intake. Accordingly, while very young males bear the least risk, and while both males and females bear an increasing share of risk as they age, males assume additional risk at a greater rate than do females as they mature.

As consumption preferences may be affected by pregnancy, nursing or illness, we investigate this possibility by parameterizing preferences in such a way that the time varying individual shifter of marginal utility may depend on pregnancy, nursing or illness. Accordingly, specify the vector of time-varying individual characteristics ζ_{it} so that it includes a dummy variable indicating pregnancy, nursing and the number of days of illness during the last month. We find that illness shocks of any household member compared to the household head have significant negative effect in the share of food expenditures.

Interestingly, neither males nor females experience much of a reduction in calories and protein when ill, despite one's presumption that ill household members are apt to be less active. In terms of magnitudes, the estimated reduction of expenditure shares, calories, and protein is larger for men than for women on average, and smaller for caloric and protein intakes than for expenditures. Surprisingly, being pregnant appears to result in a larger fall in women's share of food expenditures, calories, and protein than does being sick but these effects are not statistically significant. WHO (1985) estimates that the energy needs of well-nourished women amount to 350 Calories more per day, or roughly a 15 per cent increase, when in the second and third trimesters of pregnancy, though there's evidence that at least part of this energy cost is made up via reduced activity. Most strikingly, pregnancy seems to lead to a 16.9 per cent reduction in woman's share of household protein, while WHO guidelines suggest that such women ought to receive an increase of roughly similar magnitude. Reductions in activity will presumably have no direct effect on a pregnant woman's need for protein.

4.2. **Testing the Unitary Household Model.** The estimates presented in Table 2 shed light on the intra-household allocation of consumption given the validity of our specification of preferences and given the hypothesis that intra-household allocations are Pareto optimal, governed by (**??**). In this case, the residuals from (6) will be orthogonal to all other information, shocks, and other outcomes which might affect the household or the individuals in it. In particular, surprises in individual labor earnings ought not to have any effect on the sharing rule.

Our next order of business, then, is to construct predictions of labor earnings for different individuals. Wages in this agricultural region have considerable seasonal variation, and vary also with weather shocks. Accordingly, we use two sorts of information to predict wages. First are a variety of fixed (or slowly varying) individual characteristics, such as sex, education, age, weight, and height (and squares of these last three quantities); next are month and village specific observations and predictions of weather.

Our construction of these weather predictions is worthy of some note. From a single weather station in Malay-Balay, Bukidnon, we have monthly information about the weather in this region over the period 1961 to 1994. These data include information on maximum rainfall, humidity, the number of rainy days per month and a measure of cloudiness. We assume that the weather at time $t+1$ is unknown at time t, but that the weather history is known, and can be used to predict future weather outcomes. We use these relatively long time series on weather variables to estimate a prediction rule for these variables (after some experimentation, we settled on regressing each of these variables on lags of six, twelve, and twenty-four months). We then interact these weather variables with a complete set of village dummy variables. By themselves, these predicted weather variables explain eleven per cent of observed variation in log earnings.

When we include these weather variables interacted with municipality along with individual characteristics, we're able to account for 22 per cent of observed variation in log earnings. Education, age, and sex all are important for determining earnings; physical characteristics less so (none is individually significant in the predicted earnings regression).

In any event, we use the predicted earnings regression to construct predicted earnings y^p_{it+1} and 'surprise' earnings y^u_{it+1}, computed as the forecast error in the predicted earnings regression. We then add the change in the log of these earnings variables for both person i and the household head to the base regression (6). Results are reported in the right-hand panel of Table 2.

By introducing overidentifying individual earnings variables in these equations, one can test for perfect risk sharing within the household. The results show clearly a rejection of full risk sharing since unpredicted individual earnings shocks have a significant positive effect on food expenditures and protein intakes. Also, predicted increase of the head's earnings have significant negative effect on other members consumption.

Our results amount to a firm rejection of the null hypothesis that surprises in earnings are orthogonal to changes in consumption shares. In particular, a surprise one per cent increase in person i's earnings leads to an estimated (and significant) 0.06 increase in i's share of food expenditures relative to the head. The estimated responses of nutrient shares to such a shock are similarly positive and significant (0.074 for calories and 0.079 for proteins).

However, more surprising is that predictable increases in the head's earnings lead to quite large increases in the head's share of expenditures and protein. In particular, we estimated that a one percent increase in the head's predicted earnings leads to a 0.43 per cent increase in the head's share of food expenditures, a 0.68 per cent increase in the head's share of calories, and a 0.63 per cent increase in the head's share of protein. This is inconsistent not only with the strong predictions of our model of the unitary household, but is also inconsistent with much less restrictive models, a point we shall return to later.

4.3. **Tests of the Nutritional Investment Model.** Our second model has the property that the household may make investments in the nutrition of members where the marginal return to those investments may be particularly high. Without much better data on production, this is hard to test directly. However, once again we can marshal some evidence which is at least extremely suggestive.

In particular, as discussed in Section 3, we can also use the consumption expenditures by food categories to implement the same tests.[4] In particular, we can look to see how shocks to earnings affect different of these food categories. The key to our test is to note that if nutritional investment is driving changes in shares, then predicted or realized changes in earnings ought to affect nutritional intakes; e.g., a family member who is expected to spend long hours behind a plow might plausibly receive extra protein in advance of plowing, and extra calories during the same period as the plowing occurs. However, if two different sorts of food both have the same nutritional value, but consumption of one sort gives higher levels of utility (and hence is presumably more costly), then our model of nutritional investment would predict increases in calories and protein in response to increases in earnings, but *not* necessarily in categories of food which are superior in terms of utility.

Following this logic, we reorganize our food into groups according to type, rather than nutrients. These groups include rice; corn; and other staples; meat and fish; vegetables; snacks and fruit; and a residual "other" category. Basic results from our specification for the naive collective model appear in the left-hand panel of Table 4.

The expenditure elasticity of individual demand for these food groups is typically much greater than it is for total food expenditures; in particular, a one per cent increase in the head's expenditures on, e.g.,

[4] Because consumption of some food items is sometimes zero, we replace the logarithmic transformation of food expenditures by the inverse hyperbolic sine (Robb et al., 1992; Browning et al., 1994).

	Rice	Corn	Staples	Meat	Veg.	Snacks	Other	F (p-value)
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Male	0.7022*	0.6834*	0.9107*	0.8774*	0.5682*	0.5389*	0.8720*	2539.4462
	(0.0107)	(0.0106)	(0.0202)	(0.0166)	(0.0128)	(0.0154)	(0.0145)	(0.0000)
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Female	0.7641*	0.7329*	0.9456*	0.8671*	0.7086*	0.6182*	0.9194*	4351.6155
	(0.0094)	(0.0088)	(0.0175)	(0.0132)	(0.0102)	(0.0125)	(0.0115)	(0.0000)
$\frac{\delta}{\theta' \upsilon_i}$: Age male	0.0648	0.0838	0.0859	0.1764	0.1635*	−0.0313	−0.0054	1.7067
	(0.0752)	(0.0701)	(0.0768)	(0.1179)	(0.0606)	(0.0942)	(0.0701)	(0.1024)
$\frac{\delta}{\theta' \upsilon_i}$: Age female	−0.0422	0.1215	−0.1371	−0.1480	0.1944*	−0.0407	0.0448	1.9102
	(0.0855)	(0.0796)	(0.0872)	(0.1340)	(0.0686)	(0.1071)	(0.0796)	(0.0636)
Days sick, male	−0.0009	−0.0014	−0.0047*	−0.0087*	−0.0050*	−0.0109*	−0.0067*	6.4580
	(0.0021)	(0.0020)	(0.0022)	(0.0034)	(0.0017)	(0.0027)	(0.0020)	(0.0000)
Days sick, female	0.0028	−0.0022	−0.0034	−0.0030	−0.0037*	−0.0031	−0.0024	2.3232
	(0.0019)	(0.0018)	(0.0019)	(0.0030)	(0.0015)	(0.0024)	(0.0018)	(0.0228)
Pregnant	0.0635	−0.1089*	−0.0002	−0.0854	0.0145	−0.0766	−0.0465	1.1984
	(0.0544)	(0.0507)	(0.0555)	(0.0853)	(0.0436)	(0.0681)	(0.0507)	(0.2996)
Nursing	0.0166*	0.0008	−0.0028	0.0057	0.0104	−0.0090	−0.0037	1.4685
	(0.0073)	(0.0068)	(0.0075)	(0.0115)	(0.0059)	(0.0092)	(0.0068)	(0.1733)
Second quarter	0.0202	0.0602*	0.0143	0.0579*	0.0639*	0.0252	0.0635*	15.8113
	(0.0113)	(0.0105)	(0.0116)	(0.0178)	(0.0096)	(0.0143)	(0.0106)	(0.0000)
Third quarter	0.0151	0.0251*	−0.0117	0.0061	0.0058	0.0057	0.0059	1.5856
	(0.0115)	(0.0107)	(0.0117)	(0.0180)	(0.0092)	(0.0143)	(0.0107)	(0.1344)
Fourth quarter	−0.0117	−0.0109	0.0140	0.0415*	−0.0188*	−0.0313*	−0.0485*	5.4690
	(0.0115)	(0.0107)	(0.0117)	(0.0180)	(0.0092)	(0.0143)	(0.0107)	(0.0000)

TABLE 3. Expenditure shares for different food groups within the household. Point estimates may be interpreted as changes in person i's share of expenditures on each of the various food groups relative to the share of the household head. Figures in parentheses are standard errors.

	Rice	Corn	Staples	Meat	Veg.	Snacks	Other	F (p-value)
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Male	0.7021*	0.6835*	0.9097*	0.8747*	0.5666*	0.5402*	0.8706*	2534.7806
	(0.0107)	(0.0106)	(0.0203)	(0.0166)	(0.0128)	(0.0154)	(0.0144)	(0.0000)
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Female	0.7640*	0.7332*	0.9449*	0.8651*	0.7084*	0.6178*	0.9196*	4348.1605
	(0.0095)	(0.0088)	(0.0175)	(0.0132)	(0.0102)	(0.0125)	(0.0115)	(0.0000)
$\frac{\delta}{\theta' \upsilon_i}$: Age male	0.0690	0.0845	0.0812	0.1799	0.1277*	0.0004	−0.0198	1.3291
	(0.0758)	(0.0706)	(0.0774)	(0.1185)	(0.0609)	(0.0950)	(0.0707)	(0.2316)
$\frac{\delta}{\theta' \upsilon_i}$: Age female	−0.0385	0.1203	−0.1385	−0.1447	0.1753*	−0.0238	0.0372	1.6825
	(0.0856)	(0.0797)	(0.0874)	(0.1339)	(0.0686)	(0.1072)	(0.0797)	(0.1081)
Days sick, male	−0.0009	−0.0013	−0.0048*	−0.0086*	−0.0051*	−0.0108*	−0.0067*	6.4533
	(0.0021)	(0.0020)	(0.0022)	(0.0034)	(0.0017)	(0.0027)	(0.0020)	(0.0000)
Days sick, female	0.0028	−0.0021	−0.0035	−0.0030	−0.0038*	−0.0030	−0.0024	2.3749
	(0.0019)	(0.0018)	(0.0019)	(0.0029)	(0.0015)	(0.0024)	(0.0018)	(0.0200)
Pregnant	0.0617	−0.1061*	−0.0012	−0.0863	0.0157	−0.0782	−0.0459	1.1771
	(0.0544)	(0.0507)	(0.0555)	(0.0851)	(0.0436)	(0.0682)	(0.0507)	(0.3119)
Nursing	0.0168*	0.0014	−0.0031	0.0068	0.0112	−0.0094	−0.0035	1.5759
	(0.0073)	(0.0068)	(0.0075)	(0.0115)	(0.0059)	(0.0092)	(0.0068)	(0.1373)
Second quarter	0.0145	0.0515*	0.0178	0.0418*	0.0696*	0.0183	0.0666*	14.4034
	(0.0116)	(0.0108)	(0.0119)	(0.0183)	(0.0098)	(0.0148)	(0.0109)	(0.0000)
Third quarter	0.0189	0.0338*	−0.0132	0.0210	0.0173	−0.0029	0.0097	2.5515
	(0.0122)	(0.0114)	(0.0125)	(0.0191)	(0.0098)	(0.0153)	(0.0114)	(0.0126)
Fourth quarter	−0.0153	−0.0191	0.0136	0.0261	−0.0427*	−0.0120	−0.0571*	5.7221
	(0.0136)	(0.0126)	(0.0138)	(0.0212)	(0.0108)	(0.0170)	(0.0126)	(0.0000)
y^p_{1t+1}	−0.1184	−0.2101*	0.0289	−0.3705*	−0.2481*	0.1916	−0.0849	3.1803
	(0.0996)	(0.0926)	(0.1015)	(0.1557)	(0.0796)	(0.1246)	(0.0926)	(0.0023)
y^u_{1t+1}	−0.0090	0.0084	−0.0092	0.0066	0.0110	0.0000	−0.0000	0.5497
	(0.0106)	(0.0098)	(0.0108)	(0.0165)	(0.0085)	(0.0132)	(0.0098)	(0.7971)
y^p_{it+1}	−0.0313	0.0114	0.0828	0.0268	0.6635*	−0.5834*	0.2600	3.9707
	(0.1881)	(0.1748)	(0.1918)	(0.2940)	(0.1502)	(0.2352)	(0.1748)	(0.0002)
y^u_{it+1}	0.0286	0.0097	−0.0051	0.0672*	0.0107	0.0087	−0.0035	1.0016
	(0.0190)	(0.0177)	(0.0194)	(0.0297)	(0.0152)	(0.0238)	(0.0177)	(0.4278)

TABLE 4. Expenditure shares for different food groups within the household. Point estimates may be interpreted as changes in person i's share of expenditures on each of the various food groups relative to the share of the household head. Figures in parentheses are standard errors.

rice will be matched by a 0.72 per cent increase in rice expenditures for males in the household, and a 0.78 per cent increase for females. However, unlike total expenditures, shares of expenditures for most food groups do not increase sharply with age. Only for vegetables do expenditure shares increase significantly with age; evidence, perhaps, that young children aren't particular fond of vegetables.

Sickness and pregnancy have effects on consumption shares not unlike the effects seen in Table 2; in particular, both sick males and females receive a significantly smaller share of snacks and fruit, sick males receive a smaller share of meat, vegetables, and the residual "other" category; and sick females receive a significantly smaller share of "other staples". Pregnancy leads to a substantial and significant fall in the share of corn, the principal staple in this region.

When, as in Table 2 we add earnings changes to the base specification, we find even stronger evidence against the naive collective household model. Increases in predicted wages relative to the household head imply much larger shares of rice, meat and fish, and vegetables. The effects of unpredicted changes are much weaker, with significant changes in shares of "other staples" and meat; the magnitude of the estimated effects of these unpredicted changes is much smaller than for predicted changes.

We've rejected the full risk-sharing predicted by the naive collective model; what about the model with incentives? Here we exploit the fact that in the absence of nutritional investments, our model predicts that all incentives will be provided via variation in the quantity of nutrients, not the quality. Thus, the cost per unit of each nutrient ought not to vary across household members. If, on the other hand, one household member's calories are provided at a cost considerably greater than the cost of calories for another, this suggests that part of the aim of the food allocation is to provide some additional utility to the household member with the higher-cost nutrients. If, moreover, we observe that people with positive shocks to off-farm earnings suddenly receive their calories by eating more expensive sorts of food, we would regard this as strong evidence against a model of pure nutritional investment in favor of a model in which the provision of food is designed to provide some sort of incentives.

We measure quality of nutrients by the simple device of using the *cost per Calorie* and the *cost per gram of protein*. Relating quality for person i to the household head, we have the prediction that

$$\Delta \log \varphi_{it}^{k} = \Delta \log \varphi_{1t}^{k} + \epsilon_{it},$$

	Calorie cost	Protein cost	F (p-value)	Calorie cost	Protein cost	F (p-value)
$\frac{\theta' v_1}{\theta' v_i}$: Male	0.1653*	0.4619*	808.1813	0.1647*	0.4624*	804.2435
	(0.0046)	(0.0102)	(0.0000)	(0.0046)	(0.0102)	(0.0000)
$\frac{\theta' v_1}{\theta' v_i}$: Female	0.1800*	0.3921*	1046.8905	0.1800*	0.3916*	1043.4241
	(0.0042)	(0.0081)	(0.0000)	(0.0042)	(0.0081)	(0.0000)
$\frac{\delta}{\theta' v_i}$: Age male	−0.0004	−0.0733*	15.5720	−0.0005	−0.0720*	14.4342
	(0.0006)	(0.0179)	(0.0000)	(0.0006)	(0.0181)	(0.0000)
$\frac{\delta}{\theta' v_i}$: Age female	0.0004	−0.0169	2.2345	0.0004	−0.0164	2.0961
	(0.0007)	(0.0204)	(0.1071)	(0.0007)	(0.0204)	(0.1230)
Days sick, male	−0.0001*	−0.0014*	10.2902	−0.0001*	−0.0014*	10.3112
	(0.0000)	(0.0005)	(0.0000)	(0.0000)	(0.0005)	(0.0000)
Days sick, female	−0.0000	−0.0002	1.0613	−0.0000	−0.0002	1.0436
	(0.0000)	(0.0004)	(0.3460)	(0.0000)	(0.0004)	(0.3522)
Pregnant	0.0002	0.0057	0.1016	0.0002	0.0060	0.1106
	(0.0004)	(0.0130)	(0.9034)	(0.0004)	(0.0130)	(0.8953)
Nursing	−0.0001	−0.0011	0.4124	−0.0000	−0.0011	0.3782
	(0.0001)	(0.0017)	(0.6621)	(0.0001)	(0.0017)	(0.6851)
Second quarter	−0.0003*	−0.0007	9.8664	−0.0003*	−0.0017	9.6196
	(0.0001)	(0.0027)	(0.0001)	(0.0001)	(0.0028)	(0.0001)
Third quarter	0.0004*	0.0139*	13.5745	0.0004*	0.0143*	13.1891
	(0.0001)	(0.0027)	(0.0000)	(0.0001)	(0.0029)	(0.0000)
Fourth quarter	−0.0005*	−0.0186*	24.1732	−0.0006*	−0.0184*	18.2989
	(0.0001)	(0.0027)	(0.0000)	(0.0001)	(0.0032)	(0.0000)
y^p_{1t+1}	—	—	—	−0.0009	−0.0074	1.2785
	—	—	—	(0.0008)	(0.0237)	(0.2785)
y^u_{1t+1}	—	—	—	−0.0000	0.0015	0.4585
	—	—	—	(0.0001)	(0.0025)	(0.6323)
y^p_{it+1}	—	—	—	0.0006	−0.0238	0.9175
	—	—	—	(0.0014)	(0.0448)	(0.3995)
y^u_{it+1}	—	—	—	0.0001	0.0003	0.2868
	—	—	—	(0.0001)	(0.0045)	(0.7507)

TABLE 5. Changes in the cost per calorie and cost per gram of protein for person i relative to the same costs for the male household head. Figures in parentheses are standard errors.

	Calorie cost	Protein cost	F (p-value)	Calorie cost	Protein cost	F (p-value)
$\frac{\theta' v_1}{\theta' v_i}$: Male	3.8164*	1.8719*	1615.2035	3.8253*	1.8778*	1611.7535
	(0.1087)	(0.0365)	(0.0000)	(0.1093)	(0.0367)	(0.0000)
$\frac{\theta' v_1}{\theta' v_i}$: Female	1.5882*	1.0857*	470.3805	1.5742*	1.0773*	458.5973
	(0.0985)	(0.0381)	(0.0000)	(0.0989)	(0.0383)	(0.0000)
$\frac{\delta}{\theta' v_i}$: Age male	0.0036*	−0.0183	10.1705	0.0040*	−0.0106	9.5434
	(0.0017)	(0.0257)	(0.0000)	(0.0017)	(0.0259)	(0.0001)
$\frac{\delta}{\theta' v_i}$: Age female	0.0000	0.0140	0.2853	0.0002	0.0178	0.3705
	(0.0020)	(0.0297)	(0.7518)	(0.0020)	(0.0298)	(0.6904)
Days sick, male	0.0001*	0.0009	5.4003	0.0001*	0.0009	5.4069
	(0.0000)	(0.0006)	(0.0045)	(0.0000)	(0.0006)	(0.0045)
Days sick, female	0.0000	0.0010	1.1505	0.0000	0.0009	0.9621
	(0.0001)	(0.0008)	(0.3165)	(0.0001)	(0.0008)	(0.3821)
Pregnant	0.0003	−0.0016	0.1688	0.0003	−0.0029	0.2295
	(0.0011)	(0.0159)	(0.8447)	(0.0011)	(0.0160)	(0.7950)
Nursing	−0.0000	−0.0007	0.1451	0.0000	−0.0005	0.1140
	(0.0001)	(0.0019)	(0.8649)	(0.0001)	(0.0019)	(0.8923)
Second quarter	0.0004	0.0048	1.1122	0.0004	0.0053	1.0818
	(0.0003)	(0.0039)	(0.3289)	(0.0003)	(0.0043)	(0.3390)
Third quarter	−0.0007*	−0.0112*	4.0745	−0.0005	−0.0079	1.6516
	(0.0003)	(0.0040)	(0.0170)	(0.0003)	(0.0045)	(0.1918)
Fourth quarter	0.0011*	0.0147*	8.0336	0.0008*	0.0112*	2.7021
	(0.0003)	(0.0041)	(0.0003)	(0.0004)	(0.0054)	(0.0671)
y^p_{1t+1}	—	—	—	0.0033	0.0577	0.6111
	—	—	—	(0.0035)	(0.0524)	(0.5428)
y^u_{1t+1}	—	—	—	−0.0002	−0.0098*	3.4886
	—	—	—	(0.0003)	(0.0050)	(0.0306)
y^p_{it+1}	—	—	—	−0.0055	−0.1107*	2.4266
	—	—	—	(0.0034)	(0.0504)	(0.0884)
y^u_{it+1}	—	—	—	0.0002	0.0044	0.3244
	—	—	—	(0.0004)	(0.0057)	(0.7230)

TABLE 6. Changes in the cost per calorie and cost per gram of protein for person i relative to the same costs for the female household head. Figures in parentheses are standard errors.

where the ϵ_{it} term is measurement error. We estimate these equations as for nutrients, including various characteristics as tests of the specification and instrumenting for the head's quality.

In Table 5 we report results from some regressions similar to those reported in Table 2, but in which measures of changes in calories and protein are replaced with measures of changes in the cost per calorie and changes in the cost per gram of protein.

When one looks at calorie and protein costs share equations, it appears that all household members share a lower part of the head's calorie or protein costs increase. These shares range from 14.8% for female shares of calories to 53.8% for male shares of proteins. Notably, the the cost of nutrients (and thus presumably of quality) is not shared as the model predicts. In particular, since the estimated quality elasticities differ significantly from one, it follows that the quality of foodstuffs seems to depend on the curvature of individual utility functions. This leads us to reject the hypothesis that private information alone can account for rejection of naive collective model.

We next contemplate an alternative model in which food allocation plays the dual role of providing utility and acting as a nutritional investment. Now, the individual characteristics of an individual are allowed to evolve over time. The idea here is that e.g., person i's weight at $t+1$ may depend on his weight in the previous period as well as on his consumption. Recall that the evolution of b_{it} is assumed *not* to depend on the quality of consumption; only its quantities.

The intuition behind the present test is that if a household member is given more food as an *investment*, we should see an increase in *quantity* and earnings, but can also expect a *decrease* in quality, so as to compensate for the utility increase associated with the increase in quantity.

With this intuition in hand, consulting Table 6 allows us to reject the hypothesis that variation in food allocation is a consequence solely of nutritional investments. The key here is the finding that unpredicted positive shocks to off-farm earnings (relative to the head) result in a significant increase in food quality, consistent with the idea that food quality is used in the provision of incentives, and inconsistent the hypothesis that nutritional investments alone can account for intrahousehold variation in food allocation over time. Also of considerable interest is the observation that food quality drops in response to increases in *predictable* increases in earnings. This is exactly what we'd expect in an environment in which hidden actions were important—household members ought to be rewarded for outcomes which are good compared to what was expected, so that there's an important element of what Holmström (1982) calls "relative performance evaluation."

5. Conclusion

In this paper we've constructed a direct test of the hypothesis that food is efficiently allocated within households in part of the rural Philippines. Conditional on our specification of preferences (a generalization of CES utility), we're able to reject this hypothesis, as the allocation of food expenditures, calories, and protein is significantly related to the realization of each individual's off-farm earnings.

We then turn to two alternative explanations of this feature of the data. We first consider a model in which the off-farm efforts of individual family members can't be observed, so that the allocation of food is designed to provide incentives to these workers. Second, we consider a model in which food consumption produces not only utils but also functions as a form of nutritional investment, which may be used to directly influence the marginal productivity of workers. A third model supposes that food is used to provide incentives for workers, whose labor effort may be hidden from the household head. Of these two motives (investment and incentives), we are able to reject the hypothesis that changes in the allocation of food are used *solely* to provide incentives, and are similarly able to reject the hypothesis that changes in the allocation of food are used solely as a form of nutritional investment. We're left with evidence that households in this setting allocate food both to provide incentives and as a form of nutritional investment.

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