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

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

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 "unitary household" model, associated with Samuelson (1956) and Becker (1974). In Becker's formulation, an altruistic household head dictates allocations of goods such as food and leisure, giving more to some (favored) dependents, and less to others. A celebrated prediction of this model is the so-called "Rotten Kid Theorem"; given the ability to structure incentives within the household, the head can induce even entirely selfish children to act in the interests of the altruistic head (and by extension, in the interests of the entire household).

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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 wish to 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 by looking at the response of individual nutritional status to sickness 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 anthropometric outcomes. 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 simple *unitary* dynamic model in which an altruistic head allocates consumption goods and assigns activities to other household members. From this model we derive a simple restriction on household members' marginal rates of substitution. Working with a parametric representation of individuals' utility functions, we estimate a vector of preference parameters, which allows us to characterize changes in intrahousehold sharing rules as a function of individual characteristics such as age and sex.

Third, in Section 4, we construct a less restrictive model, which allows for the possibility that at least some of the activities undertaken by some of the members of the household can't be directly observed by the head. Accordingly, the intra-household sharing rule must be incentive compatible. The key difference between this model and the unitary 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 a weaker version of the unitary household restriction will hold.

In Section 5, we consider the possibility that food consumption influences future productivity (consumption produces both direct utility, and also represents a sort of human capital investment which influences labor productivity). This leads us to consider a different sort of model in the spirit of Stiglitz (1976). In this model there is no private information and hence no need to provide incentives, but the head takes into account the effect that consumption will have on the productivity of various household members. This model also implies a distinct set of restrictions on household members' marginal rates of substitution, and we provide a direct test. Section 7 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 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.

	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
≤ 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
≤ 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
≤ 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.

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. The Basic Model

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 $t = 0, 1, \ldots T$, where T may be infinite. During each period, member i consumes a K-vector of goods $c_{it} = (c_{it}^1, \ldots, c_{it}^K)$. At the same time, i undertakes m additional activities a_{it}, which may include things from which she derives pleasure (say dancing, playing games, or dressing up), and others which she finds unpleasant (e.g., plowing a field, watching a child, or cleaning the stables).

Household member i derives direct utility from consumption and activities. Further, at time t person i possesses a set of characteristics (e.g., gender, weight, age) which we denote by the vector b_{it}. These characteristics may have an influence on the utility she derives from both consumption and activities. Thus, we write her momentary utility at t as some $U(c_{it}, b_{it}) + Z_i(a_{it}, b_{it})$, where the function U is assumed to be increasing, concave, and continuously differentiable in each of the consumption goods.

Of course, unpleasant activities aren't undertaken for their own sake; rather, they may be useful in production. Let y be a vector of goods (e.g., corn, sugarcane, household services). In general, there will be uncertainty in production; we regard y as a random variable with joint p.d.f. $f(y|a)$.

We're interested in characterizing the set of efficient allocations for the household. Following Becker (1974), we imagine that the altruistic household head is responsible for allocating consumption and assigning activities within the household; however, it's important to note that this is simply a device for characterizing the set of efficient allocations. As forcefully argued by Chiappori (1988, 1992), in a static model the restriction of efficiency tells us nothing about the *shares* of consumption we expect to observe in the household (in our setting, the hypothesis of efficiency tells us nothing about the altruism of the head). However, in a dynamic setting, the hypothesis of efficiency puts very strong restrictions on the evolution of these shares, and it is these restrictions which we exploit in this paper.

In any event, the household head associates an altruism weight with the utility of each household member (with the normalization that the weight for the head is equal to one). We generalize the usual problem by permitting this weight to vary over time. In particular, let the altruism weight associated with member i's utility at time t be given by $\alpha_{it} \in (0, 1]$, and suppose that the evolution of altruism over time is given by

$$\log \alpha_{it+1} = \log \alpha_{it} + \epsilon_{it+1} \tag{1}$$

where $\mathrm{E}_t(\alpha_{it+1}/\alpha_{it}) = 1$. Note that having a constant weight over time (the usual case) is a special instance of (1).[1]

We formulate the problem facing the head recursively. At the beginning of a period, the head takes as given an n-vector reflecting his current sentiments toward other household members (α), a list of the characteristics of household members (b), prices (p), and the total of household financial resources x. Given his preferences, he then chooses consumptions and allocations subject to the constraints implied by these prices and resources. In particular, let $H(\alpha, p, x)$ denote the discounted, expected utility of the head given the current state, and let this function satisfy

$$H(\alpha, p, x, b) = \max_{\{(c_i, a_i)\}_{i=1}^n} \sum_{i=1}^n \alpha_i \left(U(c_i, b_i) + Z_i(a_i, b_i)\right)$$
$$+ \beta \int H\left(\hat{\alpha}, \hat{p}, \hat{p}' \sum_{i=1}^n y_i, \hat{b}\right) dG(\hat{\alpha}, \hat{p}, y_1, \ldots, y_n, \hat{b} | \alpha, p, a_1, \ldots, a_n, b)$$

subject to the household budget constraint

$$p' \sum_{i=1}^n c_i \leq x. \tag{2}$$

Here variables with 'hats' denote future realizations of the variable, and the distribution function G denotes the joint distribution of next period's prices and output for each of the n household members given this period's activities and prices.

It's very important to notice that in the present model consumption assignments yield utility, but do *not* affect future characteristics b. For some sorts of physical characteristics (e.g., weight) this is obviously unrealistic, and in Section 5 we relax this assumption. One of our aims is to test whether or not consumption is allocated so as to take into account the benefits of "nutritional investment;" if so, this is a factor influencing intra-household allocation which is inappropriately neglected in the standard unitary model.

First order conditions from this problem imply that

$$\frac{U_k(c_{1t}, b_{1t})}{U_k(c_{it}, b_{it})} = \alpha_{it}$$

[1]Alternatively, if one wished to avoid invoking paternal altruism, one could interpret the evolution of these coefficients as multiplicative preference shocks.

$k = 1, \ldots, K$, and $i = 1, \ldots, n$, where $U_k(c, b)$ denotes the marginal utility of the kth consumption good. From this, it's easy to see that the head will allocate consumption so that members' marginal rates of substitution are all equated. As a consequence, the unitary household model implies that

$$\frac{U_k(c_{1t+1}, b_{1t+1})/U_k(c_{1t}, b_{1t})}{U_k(c_{it+1}, b_{it+1})/U_k(c_{it}, b_{it})} = \frac{\alpha_{it+1}}{\alpha_{it}} = e^{\epsilon_{it+1}} \tag{3}$$

Accordingly, we interpret the unitary household model as implying that ratios of marginal rates of substitution between the head and any household member will vary over time only in unpredictable ways.

A solution to the sharing problem facing the household head is a set of functions which indicate the expenditures assigned to each household member i, $x_i = \tilde{e}_i(\alpha, x, p, b)$, $i = 1, \ldots, n$, and individual demand functions $c_i = c(x_i, p, b_i)$. We can use these demands to define indirect period-specific utilities from consumption,

$$v(x_i, p, b_i) = U(c(x_i, p, b_i), b_i)$$

It's also convenient to define a corresponding individual expenditure function mapping momentary utility w from consumption (given prices and characteristics) into expenditures on consumption for i, so that $x_i = e(w, p, b_i)$, satisfies

$$x_i \equiv e(v(x_i, p, b_i), p, b_i)$$

so that e is a sort of inverse of the indirect utility function v.
We can substitute the indirect utility functions v into the head's problem, yielding

$$\begin{aligned} H(\alpha, p, x, b) = \max_{\{a_1, (x_i, a_i)_{i=2}^n\}} & v(x - \sum_{i=2}^n x_i, p, b_1) + Z_1(a_1, b_1) \\ & + \sum_{i=2}^n \alpha_i (v(x_i, p, b_i) + Z_i(a_i, b_i)) \\ + \beta \int H \left(\hat{\alpha}, \hat{p}, \hat{p}' \sum_{i=1}^n y_i, \hat{b} \right) & dG(\hat{\alpha}, \hat{p}, y_1, \ldots, y_n, \hat{b} | \alpha, p, a_1, \ldots, a_n, b) \end{aligned}$$

First order conditions for this reformulation of the problem imply that $\alpha_{it} = v'(x_{1t}, p_t, b_{1t})/v'(x_{it}, p_t, b_{it})$ for $i = 1, \ldots, n$ and $t = 1, \ldots, T$. As a consequence,

$$\frac{v'(x_{1t+1}, p_t, b_{1t+1})/v'(x_{1t}, p_t, b_{1t})}{v'(x_{it+1}, p_t, b_{it+1})/v'(x_{it}, p_t, b_{it})} = \frac{\alpha_{it+1}}{\alpha_{it}} = e^{\epsilon_{it+1}} \tag{4}$$

Note the similarity of restrictions on consumptions (3) to restrictions on indirect utilities (4); we will exploit this similarity to use both expenditures and quantities of goods consumed in our empirical work.

Under the unitary model, and with the specification of preferences given above, the ratio of the intertemporal marginal rate of substitution of consumption of the household head 1 over that of person i is equal to the proportional change in the altruism parameter for person i, and can be written as

$$(5) \qquad \exp\left((\Delta\zeta_{1t+1} - \Delta\zeta_{it+1})\delta\right)\left(\frac{x^k_{1t+1}}{x^k_{1t}}\right)^{-\theta'_k\upsilon_1}\left(\frac{x^k_{it}}{x^k_{it+1}}\right)^{-\theta'_k\upsilon_i} = e^{\epsilon_{it+1}}$$

where Δ is the first difference operator. This specification of preferences is a straightforward generalization of the commonly used CRRA preferences, but it's worth noting that these preferences are not generally Gorman-aggregable. As a consequence, an efficient allocation will not generally give household members fixed shares; rather the shares will vary with total household expenditures and with changes in the time-varying characteristics of household members.

3.1. **Specification.** To conduct estimation and inference, we need to specify at least some components of agents' preferences over food consumption. The within-period allocation of total consumption expenditures x to goods with prices p can be completely characterized by an indirect period-specific utility function $\nu(p, x, b)$.[2] We're interested in characterizing food expenditures at different levels of aggregation (across goods); accordingly, for any partition of foodstuffs into S different categories, we let x^s denote expenditures on the s^th category. Then following e.g., Blundell et al. (1994), we represent these momentary preferences by the conditional indirect utility function $\nu^S(p, x^1, \dots, x^S, b)$, when the household head is constrained to spend x^s on the s^th expenditure category. When the head is not so constrained, we represent his conditional indirect utility by $\nu(p, x, b)$. The restrictions we then place on these different representations of the household head's indirect utility are given by:

Assumption 1. *The S categories of expenditures are aggregable in the sense that $\nu^S(p, x^1, \dots, x^S, b) = \nu(p, x, b)$, where $x = \sum_{s=1}^S x_r$. Further, there exist household-specific, possibly time-varying 'price indices' $\pi^S_{ht}(p)$ and a set of functions $V^S(x^1, \dots, x^S, b)$ such that the indirect*

[2]Note that such a $\nu(p, x, b)$ will be unique only up to monotone transformations which preserve concavity in x.

utility functions satisfy

$$\frac{\partial}{\partial x^s}\nu^S(p,x^1,\ldots,x^S,b) = \pi^S_{ht}(p)\frac{\partial}{\partial x^s}V^S(x^1,\ldots,x^S,b)$$

for all $s = 1,\ldots,S$.

Note that this condition is satisfied by the class of indirect utility functions having the PIGL or PIGLOG property (Muellbauer, 1975), described by Deaton and Muellbauer (1980) and widely used in the empirical literature (e.g., Blundell et al., 1993, 1994).

A consequence of Assumption 1 is that the ratio of marginal utilities of expenditures s of any two members of household h does not depend on the unknown price index $\pi^S_{ht}(p)$. Specifying the function V^S will then allow us to work with within-household ratios of marginal utilities of consumption.

We want to permit a great deal of heterogeneity in preferences over different consumption goods. 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), and let ζ_{it} denote time-varying characteristics of the same person (such as age and health). Both υ_i and ζ_{it} are assumed to be observed by the econometrician. In contrast, let ξ_i denote time-invariant characteristics of person i which aren't observed in the data.

Recalling that consumption consists of K elements $(c^1,...,c^K)$, we parameterize the utility U of person i at date t by

$$U\left(c_{it},b_{it}\right) = \exp\left(\upsilon_i'\gamma + \zeta_{it}'\delta + \xi_i\right)\sum_{k=1}^{K} A^k_i B^k_t \frac{(c^k_{it})^{1-\theta_k'\upsilon_i}}{1-\theta_k'\upsilon_i} \tag{6}$$

Given the previous remarks, an almost identical parameterization will serve for modeling the indirect utility of expenditures $(x^1,...,x^S)$. Here $(\gamma,\delta,\theta_1,...,\theta_K)$ are each vectors of unknown parameters. Thus, the factor $\exp\left(\upsilon_i'\gamma + \zeta_{it}'\delta + \xi_i\right)$ allows the utility (and marginal utility) of all consumption to vary according to both observed and unobserved characteristics (as in, e.g., Blundell et al., 1994). Note, in particular, that one can model differences in the utility derived from consumption foodstuffs according to features such as age and sex. The factors $\{A^k_i\}^K_{k=1}$ govern the relative, idiosyncratic utility a given person derives from different consumption goods: think of invariant differences in preferences over vegetables and sweets, for example. In contrast, the factors $\{B^k_t\}$ govern time-varying differences in preferences over different commodities; think of seasonal differences in preferences for starchy foods. Finally, the linear functions $\theta_k'\upsilon_i$ can be regarded as the relative risk aversion person i has over variation in the consumption of good k, so that risk attitudes can vary according to sex, ethnicity, or other time-invariant characteristics.

4. Intra-household Moral Hazard

In this section, we modify the basic model of Section 3 by considering the possibility that some of the activities undertaken by household members may not be observed by the head. By an appeal to the Revelation Principle (Myerson, 1979) the problem facing the head may be written just as in Section 3, but with the addition of some incentive compatibility constraints guaranteeing that no member has an incentive to engage in any but the activities recommended by the head.

Preferences, technology, and the evolution of the head's altruism weights are as in Section 3; the only modification to the environment is that we imagine that the head cannot observe activities $\{a_{it}\}$. While the head can still recommend particular activities, these recommendations must now be incentive compatible. In general, an efficient incentive-compatible solution to the head's problem will involve making current and future utility dependent on observable production outcomes $\{y_{it}\}$, since the probability of these different outcomes depends on the unobservable actions taken.

Rather than attempting to provide a complete characterization of the constrained efficient sharing arrangement in this environment, we instead look for a partial characterization analogous to equations (3) and (4). To do so, we examine one of the sub-problems facing the head, related to the scheduling of expenditures for i's consumption in two adjacent periods. In particular, suppose that member i currently expects a utility of w_{it} at time t. Now, let the head contemplate a reduction of consumption expenditures for i in the current period corresponding to a reduction of η_i utils for member i, and a corresponding increase in expenditures in the subsequent period corresponding to an increase of η_i/β utils, regardless of the subsequent state, so that the head's utility at t and $t+1$ is

$$\begin{aligned} V\left(\eta_2,...,\eta_n\right) &= v\left(x_t - \sum_{i=2}^{n}\left(e\left(w_{it}-\eta_i, p_t, b_{it}\right)\right), p_t, b_{1t}\right) \\ &\quad +\beta E_t v\left(x_{t+1} - \sum_{i=2}^{n}\left(e\left(w_{it+1}-\eta_i/\beta, p_{t+1}, b_{it+1}\right)\right), p_{t+1}, b_{1t+1}\right) \\ &\quad +\sum_{i=2}^{n}\alpha_{it}\left(w_{it}-\eta_i\right) + \beta E_t\left[\alpha_{it+1}\left(w_{it+1}+\eta_i/\beta\right)\right] \end{aligned}$$

Because the η_i are chosen independently of future activities and outcomes, such a rescheduling will not interact with any incentive compatibility constraints. At the optimum, $dV/d\eta_i = 0$, so that

$$v'(x_{1t}, p_t, b_{1t})e'(w_{it}, p_t, b_{it}) = \mathrm{E}_t[v'(x_{1t+1}, p_{t+1}, b_{1t+1})e'(w_{it+1}, p_{t+1}, b_{it+1})]$$

for all i=1,..,n. This is essentially just an Euler equation for the household head; similar results have been derived in the dynamic agency literature for purely selfish agents (Rogerson, 1985), and have been tested in an inter-household context by Ligon (1998). Since the expenditure function e is the inverse of the indirect utility function v, by the inverse function theorem this expression can be rewritten as

$$\frac{v'(x_{1t}, p_t, b_{1t})}{v'(x_{it}, p_t, b_{it})} = \mathrm{E}_t\left[\frac{v'(x_{1t+1}, p_{t+1}, b_{1t+1})}{v'(x_{it+1}, p_{t+1}, b_{it+1})}\right] \tag{7}$$

that is, ratios of marginal indirect utilities obey a martingale. Further, from the properties of the indirect utility function, a similar restriction holds for direct marginal utilities:

$$\frac{U_k(c_{1t}, b_{1t})}{U_k(c_{it}, b_{it})} = \mathrm{E}_t\left[\frac{U_k(c_{1t+1}, b_{1t+1})}{U_k(c_{it+1}, b_{it+1})}\right] \tag{8}$$

Note that this partial characterization of private information constrained efficiency does *not* depend on altruism in any way, except that more altruism on the part of head toward member will increase expected levels of member's consumption.

5. Nutritional Investment

We now extend the model of Section 3 in another direction, and take into account the possibility that current consumption provides some sort of nutrition to household members, which in turn may affect the future (dis)utility associated with some particular activities. This new model is very much in the spirit of, say, Stiglitz (1976), or Dasgupta and Ray (1986).

Notation is as in Section 3. Recall that at date t, member i is described by some set of physical characteristics b_{it}, which may include things like gender, height, weight, health, and so on. Earlier, b_{it} evolved according to some unspecified stochastic process, but this evolution was assumed to be independent of current activities and consumption. In this extended version of the model, member i consumes a K-vector of goods c_{it}, as before, but now she derives not only direct utility from this consumption, but may also derive l nutrients s_{it}, related to consumption by

$$s_{it} = \Pi(c_{it})$$

where $\Pi : \mathbb{R}^K \to \mathbb{R}^l$ can be thought of as the mapping from food into nutrients. Note that the vector of goods consumed may include some items with no nutritional value. At the same time, i undertakes m additional activities a_{it}, as before. Momentary utility for person i at t is given by $U(c_{it}, b_{it}) + Z_i(a_{it}, b_{it})$.

The key difference between this model and the model of Section 3 is that the physical characteristics of household members evolve in response to nutrition and activities, according to a law of motion M, so that

$$b_{it+1} = M(a_{it}, b_{it}, s_{it}).$$

Note that this law of motion permits consumption at time t to influence subsequent characteristics, since nutrients s_{it} depend on consumption via the nutrition function Π. Though this law of motion is a first-order Markov process, one could allow more complicated temporal dependence through clever specification of the vector b_{it}, permitting it, for example, to include lagged variables. So if, say, bone density depends on current and lagged calcium intake, this can be captured simply by adding lagged calcium intake to the vector b_{it}, and modifying the function M accordingly.

As before, let y be a vector of goods (e.g., corn, sugar, household services). In general, there will be uncertainty in production; we regard y as a random variable with joint p.d.f. $f(y|a)$. Note the implicit restriction: the probability of corn yields being high depends on the field being properly plowed, but it doesn't depend on the physical characteristics of the person who actually performed the plowing.

The new problem facing the household head requires him to take into account the influence of current consumption on future productivity:

$$H(\alpha, p, x, b_1, \ldots, b_n) = \max_{\{(c_i,a_i)\}_{i=1}^n} \sum_{i=1}^n \alpha_i \left(U(c_i, b_i) + Z_i(a_i, b_i)\right)$$

$$+\beta \int H\left(\hat{\alpha}, \hat{p}, \hat{p}' \sum_{i=1}^n y_i, \hat{b}_1, \ldots, \hat{b}_n\right) dG(\hat{\alpha}, \hat{p}, y_1, \ldots, y_n | \alpha, p, a_1, \ldots, a_n)$$

subject to the budget constraint

$$p' \sum_{i=1}^n c_i \leq x \tag{9}$$

and the law of motion for physical characteristics

$$\hat{b}_i = M(a_i, b_i, c_i). \tag{10}$$

The distribution function G denotes the joint distribution of next period's prices and output for each of the n household members given this period's activities and prices. The value $\hat{p}' \sum_{i=1}^{n} y_i$ represents the next period budget of the household. Note that G no longer governs the evolution of b_i; rather, this evolution proceeds according to (10).

6. 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 household head's altruism parameters $\{\alpha_t^i\}$. The first model is a simple version of the unitary 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 time-varying altruism of the head toward 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 (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. Even if there are changes in a member's productivity, but these changes are predictable, then that won't produce any change in that person's expected share, though such a change may lead to a *permanently* higher share of resources being assigned to that person.

The third 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.

6.1. **Tests of the Unitary Household Model.** Equation (5) gives a relationship between the growth rate of consumption and expenditures for the household head and that of each household member if preferences are as assumed in (6) 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. As a first pass at testing this restriction, we take logs of (5) and rearrange, yielding the estimating equation

$$\Delta \log(x_{it}^k) = \Delta \log(x_{1t}^k) \frac{\theta_k' \upsilon_1}{\theta_k' \upsilon_i} + (\Delta\zeta_{it} - \Delta\zeta_{1t})' \frac{\delta}{\theta_k' \upsilon_i} + \frac{\epsilon_{it}}{\theta_k' \upsilon_i} \tag{11}$$

which characterizes allocations under the unitary household model. It's important to 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 (11) 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 equation (11).

It may be worth dwelling on the interpretation of (11). 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 (11). 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 (11) are reported in Table 2. Here we exploit the relationship between ratios of direct and indirect utility given by (3) and (4) to estimate a system of three equations, each of the form of (11), 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 an iterated feasible generalized least squares procedure to estimate this system of seemingly unrelated regressions.

An examination of the results of Table 2 leads to several conclusions. 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 0.11 for male sharing of calories to 0.34 for female sharing of expenditures. Estimates of these sharing parameters are slightly (but significantly) greater for females than for males. On a strict interpretation of (11) 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, males in the household bear less risk than do females *ceteris paribus*. Further, the head's tolerance of variation in the consumption of protein and calories (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 protein and calories to a greater extent than does the head.

In contrast to results for risk attitudes, maturity has a very different influence on consumption shares across sexes. In particular, on average

	Food expend.	Calories	Protein	Food expend.	Calories	Protein
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Male	0.304*	0.11*	0.189*	0.304*	0.11*	0.189*
	(28.93)	(23.69)	(26.15)	(28.97)	(23.61)	(26.1)
$\frac{\theta' \upsilon_1}{\theta' \upsilon_i}$: Female	0.339*	0.132*	0.226*	0.339*	0.132*	0.226*
	(39.26)	(31.12)	(34.99)	(39.35)	(31.08)	(34.98)
$\frac{\delta}{\theta' \upsilon_i}$: Age male	0.23*	0.287*	0.408*	0.22*	0.263*	0.391*
	(2.47)	(3.32)	(4.62)	(2.34)	(3.01)	(4.39)
$\frac{\delta}{\theta' \upsilon_i}$: Age female	0.166	0.208*	0.238*	0.159	0.194*	0.227*
	(1.56)	(2.12)	(2.37)	(1.5)	(1.97)	(2.26)
Days sick, male	-0.017*	-0.004	-0.009*	-0.017*	-0.004	-0.009*
	(6.35)	(1.61)	(3.5)	(6.35)	(1.65)	(3.51)
Days sick, female	-0.008*	-0.001	-0.004	-0.008*	-0.001	-0.004
	(3.41)	(0.48)	(1.65)	(3.39)	(0.46)	(1.63)
Pregnant	-0.056	-0.082	-0.125*	-0.059	-0.084	-0.126*
	(0.89)	(1.42)	(2.12)	(0.95)	(1.45)	(2.15)
Second quarter	-0.048*	-0.023	-0.03*	-0.061*	-0.027*	-0.039*
	(3.4)	(1.77)	(2.27)	(4.18)	(1.99)	(2.82)
Third quarter	0.121*	-0.034*	-0.045*	0.124*	-0.033*	-0.043*
	(8.5)	(2.57)	(3.33)	(8.7)	(2.53)	(3.15)
Fourth quarter	-0.147*	0.045*	0.096*	-0.147*	0.043*	0.096*
	(10.3)	(3.42)	(7.17)	(10.27)	(3.29)	(7.09)
y^p_{1t+1}				-0.349*	-0.259*	-0.298*
				(2.86)	(2.28)	(2.57)
y^u_{1t+1}				0.004	0.009	0.012
				(0.33)	(0.72)	(0.97)
y^p_{it+1}				0.249	0.476*	0.347
				(0.96)	(1.97)	(1.4)
y^u_{it+1}				0.047*	0.017	0.026
				(1.97)	(0.79)	(1.17)

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 t-statistics.

a one percent increase in the ratio of a male's age to head's age results in a 0.23 per cent increase in the value of food consumed by that male, a corresponding 0.29 per cent increase in calories and a 0.41 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 a (statistically insignificant) 0.17 per cent increase in the value of food consumed by that female, a corresponding 0.21 per cent increase in calories and 0.24 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 consumption preferences may be affected by pregnancy or illness, we investigate this possibility by parameterizing preferences such that the time varying individual shifter of marginal utility may depend on illness. Accordingly, specify the vector of time-varying individual characteristics ζ_{it} so that it includes a dummy variable indicating pregnancy 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, and that male household members also receive a significantly smaller share of protein. Interestingly, neither males nor females experience much of a reduction in calories when ill, despite one's presumption that ill household members are apt to be less active. In terms of magnitudes, the estimated reduction expenditure shares, calories, and protein is larger for men than for women on average, and generally 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 (even if significant only for protein). 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 pregancy, 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 12.5 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.

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 (3). In this case, the residuals from (11) 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 this 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 (11). Results are reported in the right-hand panel of Table 2.

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 lead to an estimated (and significant) 0.05 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, but of smaller magnitude and are not signficant. However, even 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 0.34 per cent increase in the head's share of food expenditures, and a 0.29 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.

Of course, as a measure of an individual's contribution to the household, off-farm earnings has some serious drawbacks. First, only about twenty per cent of the sample individuals work off-farm in any given period. Of these, about a quarter change their off-farm labor status during the sample period. Second, the decision to work off-farm entails a cost; the foregone output which could have been produced had the person remained on-farm. Since this sort of individual on-farm production isn't observed by the econometrician, it's hard to know how to interpret the coefficient estimates in Table 5. Nonetheless, under the null hypothesis of income pooling and our maintained hypotheses regarding technology and preferences, all the coefficients of income variables in Table 5 ought to be zero. Accordingly, we are able to reject the null hypothesis of full income pooling; different household members' expenditure shares change (relative to the head's share) in response to shocks to individual earnings.

6.2. **Tests of the Intra-household Moral Hazard Model.**

As we've rejected the unitary household model (conditional on our preference specification), it becomes interesting to know whether observed allocations in our data are consistent with less restrictive models. Here, we ask whether the observed food allocation might be consistent with the model of hidden actions and incentives described in Section 4. Recall from that section that such a model implies a restriction similar to but weaker than the restriction implied by the unitary household model. In particular, using the specification of preferences given in Section 3.1 we rewrite the restriction (8), yielding

$$\text{(12)}\quad \mathrm{E}_t\left[\exp\left(\Delta\zeta_{1t+1}\delta - \Delta\zeta_{it+1}\delta\right)\left(\frac{x_{1t+1}}{x_{1t}}\right)^{-\theta(v_1)}\left(\frac{x_{it}}{x_{it+1}}\right)^{-\theta(v_i)}\right] = 1,$$

where the operator E_t denotes expectations conditioned on the time t information set.

The intuition for this weaker restriction is that *surprises* in earnings may influence shares, but that predictable changes will not. Hence, our finding in Table 2 that surprises in own earnings influence shares, though at odds with the unitary household model, is perfectly consistent with model having hidden actions, in which household members are rewarded for unexpected productivity. However, it is more difficult to see how this model is consistent with our other finding that *predictable* changes in the head's earnings influence shares; since y^p_{1t+1} is in the time t information set, this seems to suggest that evidence already presented in Table 2 serves to reject our model of incentives.

	Food Exp.	Calories	Protein	Food Exp.	Calories	Protein
$\theta' \upsilon_i$: Male	0.043	0.047	0.067	0.038	0.059	0.076
	(0.283)	(0.282)	(0.426)	(0.230)	(0.329)	(0.445)
$\theta' \upsilon_i$: Female	0.015	−0.008	0.002	−0.010	−0.034	−0.022
	(0.099)	(0.050)	(0.010)	(0.057)	(0.187)	(0.116)
$\theta' \upsilon_1$: Head	0.001	0.009	0.019	−0.008	−0.016	−0.010
	(0.009)	(0.054)	(0.115)	(0.048)	(0.085)	(0.051)
δ: Age Male	0.126	0.243	0.239	−0.067	−0.051	−0.046
	(0.652)	(1.301)	(1.309)	(0.311)	(0.251)	(0.224)
δ: Age Female	2.040	2.020	2.001	3.562	3.541	3.745
	(10.444)	(10.713)	(10.829)	(16.366)	(17.085)	(18.008)
δ: Sick	−3.079	−2.945	−2.896	−3.115	−2.971	−2.944
	(15.817)	(15.679)	(15.729)	(14.400)	(14.427)	(14.253)
δ: Pregnant	−0.520	−0.504	−0.491	−0.507	−0.474	−0.469
	(2.717)	(2.723)	(2.704)	(2.385)	(2.333)	(2.301)
J (p-value)	0.000	0.000	0.000	19.879*	19.991*	20.036*
	(1.000)	(1.000)	(1.000)	(0.001)	(0.001)	(0.000)

TABLE 3. GMM estimates of expenditure and nutritional intakes within the household. Figures in the penultimate row are χ^2 statistics associated with overidentifying restrictions; in particular, the statistics in the right hand panel include tests of the hypothesis that head and own predicted and unpredicted wages are conditional mean independent of the forecast error implied by (3).

However, the evidence of Table 2 is only suggestive. Since we're estimating a version of the restriction after taking logarithms, we can't actually reject our model of incentives. In particular, it may be that our previous results are consistent with this weaker restriction since $\mathrm{E}_t(z) = 1$ does not imply that $\mathrm{E}(\log z) = 0$ but $\mathrm{E}(\log z) < 0$.

Accordingly, a proper test of our model of incentives seems to require nonlinear estimation of the parameters in (12). We first proceed by constructing a nonlinear test of the unitary household restrictions analogous to the linear tests presented in Table 2. In particular, we construct a vector of instruments z_{it}^k consisting of data on the time $t-1$ level of i's consumption in the k^th consumption category interacted with i's sex, the head's lagged level of consumption, the ratio of i's age to the age of the head (interacted with sex), lagged proportion of days sick relative to the head, and a lagged indicator variable which takes the value of one if i reports being pregnant. Using this instrument set, (3) implies

(13)
$$\mathrm{E}\left[\left(\exp\left((\Delta\zeta_{1t+1}-\Delta\zeta_{it+1})\delta\right)\left(\frac{x_{1t+1}}{x_{1t}}\right)^{-\theta(v_1)}\left(\frac{x_{it}}{x_{it+1}}\right)^{-\theta(v_i)}-1\right)\otimes z_{it}^k\right]=0.$$

We use a continuously-updated GMM estimator (Hansen et al., 1996) to estimate the parameters of this restriction. Results from this just-identified estimator are presented in the left-most panel of Table 3. The point estimates for parameters are consistent with those estimated using our linear estimator (and reported in the left-most panel of Table 2) in the sense that one can't reject the hypothesis that corresponding parameter estimates are equal; however, the precision of the parameter estimates from the GMM estimator is quite poor.

Proceeding by analogy to the estimates reported in the right-most panel of Table 2, we next augment our set of instruments by including $\{y_{1t+1}^p, y_{1t+1}^u, y_{it+1}^p, y_{it+1}^u\}$, and reestimate (13). This gives us a set of four overidentifying restrictions; the J statistics reported at the bottom of Table 3 indicate that despite the imprecision of our parameter estimates we can very decisively reject the hypothesis that earnings doesn't affect consumption shares.

Although this rejection considerably strengthens the case against the unitary household model, it doesn't answer the question of whether *predictable* changes in earnings influence consumption shares, or whether it is only *un*predictable shocks to earnings that result in changes in these shares (though either is inconsistent with the unitary model, only the former is inconsistent with our model of intra-household incentives). In particular, note that because z_{it+1}^k is in the time $t+1$ information set, these unconditional moment restrictions are implied by the unitary household model, but *not* by our model of incentives. We next modify the augmented instrument set by deleting data on unpredictable earnings. This leaves us with two overidentifying restrictions. Estimates using this instrument set are presented in the right-most panel of Table 4. We're able to reject the hypothesis that predictable earnings don't influence consumption shares, and thus to reject our model relying only on incentives.

	Food Exp.	Calories	Protein	Food Exp.	Calories	Protein
$\theta' \upsilon_i$: Male	0.043	0.047	0.067	0.039	0.070	0.086
	(0.283)	(0.282)	(0.426)	(0.253)	(0.431)	(0.540)
$\theta' \upsilon_i$: Female	0.015	−0.008	0.002	0.001	−0.032	−0.023
	(0.099)	(0.050)	(0.010)	(0.008)	(0.202)	(0.134)
$\theta' \upsilon_1$: Head	0.001	0.009	0.019	−0.004	−0.002	0.006
	(0.009)	(0.054)	(0.115)	(0.026)	(0.010)	(0.035)
δ: Age Male	0.126	0.243	0.239	−0.121	−0.128	−0.115
	(0.652)	(1.301)	(1.309)	(0.598)	(0.693)	(0.621)
δ: Age Female	2.040	2.020	2.001	2.731	2.673	2.770
	(10.444)	(10.713)	(10.829)	(13.348)	(14.297)	(14.770)
δ: Sick	−3.079	−2.945	−2.896	−3.036	−2.756	−2.740
	(15.817)	(15.679)	(15.729)	(14.908)	(14.811)	(14.680)
δ: Pregnant	−0.520	−0.504	−0.491	−0.496	−0.437	−0.435
	(2.717)	(2.723)	(2.704)	(2.472)	(2.378)	(2.358)
J (p-value)	0.000	0.000	0.000	16.934*	17.101*	17.270*
	(1.000)	(1.000)	(1.000)	(0.002)	(0.002)	(0.002)

TABLE 4. GMM estimates of expenditure and nutritional intakes within the household. Figures in the penultimate row are χ^2 statistics associated with overidentifying restrictions; in particular, the statistics in the right hand panel includes tests of the hypothesis that head and own predicted and unpredicted wages are conditional mean independent of the forecast error implied by (12).

6.3. **Tests of the Nutritional Investment Model.** Our third 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 3.1, we can also use the consumption expenditures by food categories to implement the same tests.[3] 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.,

[3]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	Rice	Corn	Staples	Meat	Veg.	Snacks	Other
$\frac{\theta(v_1)}{\theta(v_i)}$: Male	0.533*	0.509*	0.564*	0.58*	0.408*	0.288*	0.637*	0.533*	0.509*	0.563*	0.579*	0.407*	0.288*	0.637*
	(59.35)	(56.54)	(40.31)	(47.31)	(38.8)	(25.81)	(56.66)	(59.33)	(56.62)	(40.28)	(47.27)	(38.72)	(25.8)	(56.65)
$\frac{\theta(v_1)}{\theta(v_i)}$: Female	0.58*	0.58*	0.571*	0.619*	0.559*	0.351*	0.721*	0.579*	0.58*	0.57*	0.619*	0.559*	0.35*	0.722*
	(73.74)	(76.27)	(48.05)	(61.64)	(65.81)	(38.69)	(79.07)	(73.67)	(76.28)	(47.91)	(61.7)	(65.77)	(38.58)	(79.06)
$\frac{\delta}{\theta(v_i)}$: Age male	0.068	0.082	0.062	0.189	0.149*	-0.01	-0.049	0.053	0.079	0.067	0.181	0.13*	-0.002	-0.044
	(0.96)	(1.21)	(0.92)	(1.77)	(2.57)	(0.12)	(0.75)	(0.74)	(1.16)	(0.98)	(1.68)	(2.22)	(0.02)	(0.67)
$\frac{\delta}{\theta(v_i)}$: Age female	-0.002	0.118	-0.084	-0.05	0.196*	-0.057	0.063	-0.012	0.116	-0.077	-0.056	0.186*	-0.053	0.066
	(0.02)	(1.54)	(1.08)	(0.41)	(2.99)	(0.58)	(0.85)	(0.14)	(1.5)	(1.0)	(0.46)	(2.83)	(0.55)	(0.89)
Days sick, male	0.0	-0.002	-0.002	-0.012*	-0.004*	-0.013*	-0.006*	-0.0	-0.002	-0.002	-0.012*	-0.004*	-0.013*	-0.006*
	(0.01)	(1.08)	(1.24)	(3.8)	(2.24)	(5.33)	(3.03)	(0.01)	(1.08)	(1.24)	(3.79)	(2.29)	(5.3)	(3.02)
Days sick, female	0.003	-0.002	-0.003*	-0.005	-0.003	-0.005*	-0.002	0.003	-0.002	-0.003*	-0.005	-0.003*	-0.005*	-0.002
	(1.64)	(1.39)	(2.01)	(1.77)	(1.92)	(2.3)	(1.01)	(1.66)	(1.33)	(2.03)	(1.76)	(1.97)	(2.27)	(1.01)
Pregnant	0.041	-0.122*	0.021	-0.102	-0.003	-0.048	-0.01	0.04	-0.121*	0.019	-0.105	-0.006	-0.048	-0.009
	(0.86)	(2.71)	(0.47)	(1.43)	(0.08)	(0.85)	(0.22)	(0.83)	(2.69)	(0.41)	(1.48)	(0.15)	(0.84)	(0.22)
Second quarter	0.017	0.064*	-0.021*	0.008	0.005	-0.039*	0.032*	0.011	0.058*	-0.018	-0.011	0.01	-0.049*	0.034*
	(1.61)	(6.34)	(2.01)	(0.52)	(0.61)	(3.01)	(3.29)	(0.97)	(5.49)	(1.67)	(0.65)	(1.08)	(3.68)	(3.32)
Third quarter	0.024*	0.024*	0.006	0.042*	0.002	0.018	0.03*	0.025*	0.026*	0.004	0.048*	-0.0	0.021	0.029*
	(2.18)	(2.32)	(0.58)	(2.57)	(0.22)	(1.39)	(2.99)	(2.31)	(2.5)	(0.41)	(2.92)	(0.01)	(1.65)	(2.94)
Fourth quarter	-0.046*	-0.006	-0.018	0.009	-0.025*	-0.054*	-0.064*	-0.047*	-0.005	-0.018	0.009	-0.027*	-0.052*	-0.063*
	(4.21)	(0.56)	(1.72)	(0.55)	(2.79)	(4.14)	(6.43)	(4.26)	(0.47)	(1.74)	(0.58)	(3.08)	(3.99)	(6.37)
dwpp1								-0.249*	-0.163	0.071	-0.443*	-0.046	-0.137	0.065
								(2.67)	(1.84)	(0.79)	(3.16)	(0.61)	(1.23)	(0.76)
dwpu1								0.008	0.001	-0.025*	0.017	0.005	0.004	-0.004
								(0.8)	(0.09)	(2.67)	(1.13)	(0.56)	(0.36)	(0.44)
dwppi								0.316	0.063	-0.066	0.21	0.359*	-0.139	-0.099
								(1.58)	(0.33)	(0.35)	(0.7)	(2.22)	(0.59)	(0.54)
dwpui								0.021	0.002	0.011	0.058*	0.014	0.012	-0.004
								(1.18)	(0.13)	(0.65)	(2.14)	(0.98)	(0.57)	(0.23)

TABLE 5. 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 the share of the household head. Figures in parentheses are t-statistics.

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 unitary model appear in the left-hand panel of Table 5.

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., rice will be matched by a 0.53 per cent increase in rice expenditures for males in the household, and a 0.58 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.

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 unitary household model. Increases in predicted wages relative to the household head implies 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.

7. 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 seems to depend on 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 isn't used to provide incentives, but rather is a sort of nutritional investment, used to directly influence the marginal productivity of these workers. Of these two motives (incentives and investment), we are able to reject the hypothesis that changes in the allocation of food are used *solely* to provide incentives, and are able to cast doubt on the hypothesis that changes in the allocation of food is 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.

8. Appendix

8.1. **Data.** Details on the consumption data:

(1) Data on individual food intake comes from 24 hour recall interviews. Some eighty different sorts of foodstuffs are found in the data, but only 49 appear with sufficient frequency to be usefully categorized as anything but "other." These include corn (boiled/grits/meal), soft drinks, alcoholic drinks, rice and rice products, corn products, bread products, kamote, potatoes, cassava and cassava products, other root crops, sugar, cooking oil, mantika, fresh fish, dried fish, shrimps and other shellfish, cooked meat, organ meat, processed meat, chicken, bagoong, patis, buro, sardines, pork (lean), beef (lean), carabeef and goat meat, eggs (all types), milk (all types), mongo, soybeans, other dried beans, kamote tops, kangkong, malonggay, other leafy greens, squashes, tomatoes, mangoes and papayas, bananas, other fruit, and other vegetables.

(2) Calorie and protein individual intakes are computed using equivalence tables of these quantitative food intakes on each of the 49 food categories.

(3) Individual expenditures of food are computed using these food intakes valued at a household-specific price.

Details on the weather data:

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