NUTRITION AND RISK SHARING WITHIN THE HOUSEHOLD

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ABSTRACT. Using data on individual consumption from farm households in the Philippines, we construct a direct test of risk-sharing within the household. We contrast the efcient outcomes predicted by the unitary household model with the outcomes we might expect if food consumption delivers not only utils, but also nutrients affecting future productivity.

The efficiency conditions which characterize the within-household allocation of food under the unitary model are violated, as consumption responds to earnings shocks. If productivity depends on nutrition, this explains some but not all of the response, as earnings shocks effect the cost and composition of diet.

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1. INTRODUCTION

If people are risk averse, then it is efficient for those people to eliminate idiosyncratic risk by sharing it with others. Numerous authors[1] have tested the hypothesis that risk is shared efficiently *across* households by asking whether idiosyncratic variation in household expenditures is correlated with idiosyncratic variation in income. Typically the hypothesis is rejected, with possible explanations for the rejection having to do with problems of commitment or private information.

We offer another test of full risk sharing, but rather than testing risk-sharing across households, we test risk-sharing among individuals *within* a household. Within a household it seems likely the problems of commitment and private information will be small. The longevity of relationships within a household and frequent interaction and exchange of information would all tend to lead to an efficient sharing of risk.

As an empirical matter, these tests of efficient risk-sharing, whether across households or within them, all require panel data; the restrictions that are being tested are essentially inter-temporal restrictions implied by a dynamic model.

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; Bobonis, 2009). 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 panel data with household-level consumption expenditures.

In this paper we exploit a carefully collected dataset which records food consumption for each individual within a household over four successive periods, and test allocational efficiency of different goods across dates and states. By allocational efficiency we mean, in effect, that the marginal rate of substitution between any two state contingent commodities will be equated across household members.

To go with our panel dataset, we construct a dynamic model. The advantages of using a dynamic model to test the efficiency of intra-household allocations come from the fact that in an efficient allocation two different

[1]Notable examples include Mace (1991); Townsend (1994); Udry (1994); Jalan and Ravallion (1999); Angelucci and De Giorgi (2009); Mazzocco and Saini (2011).

kinds of conditions must be satisfied. First, goods such as leisure and consumption or apples and oranges be allocated efficiently across individuals *within* a period, equating different individual's marginal rates of substitution across these goods. This sort of static allocational efficiency forms the basis of tests of intra-household efficiency that are associated with the "collective" household model of Bourguignon and Chiappori (1992). These models are often interpreted in such a way as to allow changes in allocations over time in response to changes in 'distribution factors' or utility weights. But second, dynamic efficiency actually requires that these utility weights remain *constant* over time, and implies that individuals' marginal rates of substitution will be equated not just within a period, but also across periods. And this is exactly the implication exploited in the literature that tests risk-sharing across households.

Accordingly, 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, to restate, dynamic 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*.

Without pretending any sort of exhaustive comparison of our paper with existing literature, we will mention that Dercon and Krishnan (2000) also construct a test of intra-household risk-sharing using data from Ethiopia, with a model which is also dynamic by looking at the response of individual nutritional status to illness shocks. However, because they lack individual-level data on consumption or nutrition, they're forced to 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 full intra-household risk-sharing (at least for poorer households) but their results could also be consistent with efficient intra-household risk-sharing if people derive utility not only from nutrition but also directly from food consumption. Our data allow us to distinguish between these possibilities. We allow individual utility functions to depend on consumption both directly and via the influence of consumption on nutritional outcomes.

We proceed as follows. In Section 2, we provide an extended description of the data. 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 dynamic model in which utility depends on consumption, but productivity does not. 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.

In Section 4, we consider the possibility that food consumption influences future productivity. In particular, food consumption is assumed to produce both direct utility and also to be a human capital investment which influences labor productivity. This leads us to consider a model of nutritional investments, which reproduces some of the features of models formulated by, e.g., Pitt et al. (1990); Pitt and Rosenzweig (1985). In this model the head takes into account the effect that consumption will have on both utility and productivity. This model also implies a set of restrictions on household members' marginal rates of substitution which distinguish it from the first model.

Section 5 presents our main results maintaining the hypothesis of full risk-sharing, we estimate a collection of preference parameters. We permit heterogeneous risk preferences within the household, along the lines of Mazzocco (2007), and take the senior female in the household to be the household head.[2] A key result involves estimates of the ratio of relative risk aversions of the female head to the relative risk aversion of (i) males in the household; and (ii) other females in the household. Our estimates of these ratios indicate that risk aversion doesn't vary greatly across females, but that female risk aversion is roughly fifty per cent greater than the risk aversion of males. We also estimate how the ages of individual household members affects the rate of growth of nutritional intakes, and find particularly large effects for boys. We find evidence that sickness and pregnancy both have a negative effect on nutritional intakes for women. Taken together, these estimates of the effects of individual characteristics could be used to construct much richer models of household-level nutritional demand than currently prevail in the literature.

The version of the household model we estimate usefully accounts for much of the variation we observe in consumption growth rates within the

[2]It's more usual in the economics literature to imagine that adult males play the role of household head. Our assumption that females are responsible for the kinds of allocational decisions we model in this paper is motivated by our reading of the literature in anthropology and sociology which describes the division of household responsibilities in the rural Philippines (e.g., Illo, 1995; Eder, 2006).

household, but relies on the hypothesis that allocations within the household are efficient, both within and across different date-states. The hypothesis of efficiency across different date-states amounts to assuming that there is full risk sharing within the household. We test this hypothesis using an approach similar in spirit to the inter-household tests of full risk sharing devised by Townsend (1994), and ask whether unexpected changes in individual earnings have any effect on the allocation of consumption, and reject the hypothesis of full risk-sharing. Section 6 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. Though measurement error seems likely to be an important issue with these 24-hour recall data, the fact that we have independently collected data on household-level expenditures means that we have an instrument with which to address this issue. This exceptional richness of the data constitute a powerful source of identification in our empirical analysis. Food intakes

	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.

include quantity information for a highly disaggregated set of food items. Individual food expenditures can be computed using direct information on the prices of foods purchased, and on quantities consumed by the individual. The survey is also designed to measure food consumed outside of the household (so that there is no "flypaper" effect as in Jacoby (2002)).

Later in the paper we will concern ourselves with changes in individuals' consumption, intentionally neglecting to explain differences in *levels* of consumption, as these may depend on individuals' unobservable characteristics. 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. Full Risk Sharing Within the Household

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 $c_{it} = (c_{it}^1, ..., c_{it}^K)$. At the same time, i undertakes m additional activities a_{it}, which may include leisure and labor (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. The function Z_i captures the (dis)utility associated with activities, but is allowed to depend on both a_{it} and on b_{it}. In this way we capture the idea that the same tasks may involve different costs for people with different characteristics: for example, if a_{it} is the activity of plowing a field, it's reasonable to think that the disutility of that task will be greater for a young child than for a stronger adult male.

Of course, labor activities are useful for production, in particular agricultural production. Let y be a vector of goods (eg., corn, sugarcane, household services). In general, there will be uncertainty in production; and y is a random variable whose joint p.d.f will depend on a and on other observable factors w (such as weather).

Following Becker (1974), we imagine that the altruistic household head is responsible for allocating consumption and assigning activities within the household; however, we regard this simply as a device for characterizing the set of Pareto optimal allocations. As argued by Chiappori (1988, 1992), in a static model the restriction of efficiency tells us nothing about the *levels* 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 Pareto optimality puts very strong restrictions on the evolution of these shares, and it is these restrictions which we exploit in this paper.

In any event, we associate a Pareto weight with the utility of each household member (with the normalization that the weight for the head is equal to one). The weight for the ith household member can be interpreted as reflecting the altruism of the household head toward i. In particular, let the altruism weight associated with member i's utility be given by $\alpha_i \in (0,1]$,[3] and let α_1 (the head's weight) be normalized to one.

We formulate the problem facing the head (or social planner) recursively. At the beginning of a period, given a list of the characteristics of household members (b); prices (p); the total of household expenditures for the period x; and a collection of exogenous observables w, she then chooses consumptions and allocations subject to the constraints implied by these prices and resources. Let $H(p,x,b,w)$ denote the discounted, expected utility of the head given the current state, and let this function satisfy

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

subject to the household budget constraint

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

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, prices, and other observables w.

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 4 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 here.

Without nutritional investment, the first order conditions from this problem imply that

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

$k = 1, \ldots, K$, 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 consumption

[3] The literature on intrahousehold allocation sometimes treats these weights as functions of endowments or other 'distribution factors.' But, as Bourguignon et al. (2009) point out, this won't do in a dynamic model with efficient allocations. In our setting, changes in the weights would be inefficient.

is allocated so that members' marginal rates of substitution are all equated. This implies full risk sharing, as that

$$\frac{U_k(c_{1t+1}, b_{1t+1})}{U_k(c_{1t}, b_{1t})} = \frac{U_k(c_{it+1}, b_{it+1})}{U_k(c_{it}, b_{it})} \tag{2}$$

This implies that the intertemporal marginal rates of substitution of the head and any other household member will be equated at every period, and in every state.

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, $x_i = \tilde{e}_i(x, p, b)$, $i = 1, \ldots, n$, 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,

$$v(x_i, p, b_i) \equiv U(c(x_i, p, b_i), b_i).$$

It's also convenient to define a corresponding individual expenditure function mapping momentary utility w from consumption for an individual (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 the inverse of the indirect utility function v.

Substituting the indirect utility function v into the head's problem yields

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

Let the notation $v'(x, p, b)$ denote the partial derivative of v with respect to expenditures x. First order conditions for this reformulation of the problem imply that $v'(x_{1t}, p_t, b_{1t}) / v'(x_{it}, p_t, b_{it}) = \alpha_i$ for $i = 1, \ldots, n$ and $t = 1, \ldots, T$. As a consequence,

$$\frac{v'(x_{1t+1}, p_{t+1}, b_{1t+1})}{v'(x_{1t}, p_t, b_{1tf})} = \frac{v'(x_{it+1}, p_{t+1}, b_{it+1})}{v'(x_{it}, p_t, b_{it})}. \tag{3}$$

Note the similarity of restrictions on consumptions (2) to restrictions on indirect utilities (3); we will exploit this similarity to use both expenditures and quantities of goods consumed in our empirical work.

To conduct estimation and inference, we need to specify at least some components of agents' preferences over food consumption. At the same time, because children's and adults' food preferences may be quite different, we want to permit a great deal of heterogeneity in preferences over different consumption goods. Accordingly, following Dubois (2000) 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_{it} denote unobserved, time-varying characteristics or preference shocks of person i at time t.

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

$$U\left(c_{it}, b_{it}\right) = \sum_{k=1}^{K} \exp\left(\upsilon_i'\gamma_k + \zeta_{it}'\delta_k + \xi_{it}\right) A_i^k B_t^k \frac{(c_{it}^k)^{1-\theta_k'\upsilon_i}}{1-\theta_k'\upsilon_i}. \tag{4}$$

Here $(\gamma, \delta, \theta_1, ..., \theta_K)$ are each vectors of unknown parameters. Thus, the factor $\exp(\upsilon_i'\gamma + \zeta_{it}'\delta + \xi_{it})$ 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 consuming foodstuffs according to features such as age and sex. The (possibly unobserved) factors $\{A_i^k\}_{k=1}^K$ 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 $\{B_t^k\}$ 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. Given our previous remarks, an almost identical parameterization will serve for modeling the indirect utility of expenditures.

With the specification of preferences given above, the intertemporal marginal rate of substitution of consumption of the household head 1 is equal to the same marginal rate of substitution for person i, and can be written as

$$\exp(\Delta\zeta_{1t+1}'\delta_k + \Delta\xi_{1t+1}) \left(\frac{x_{1t+1}^k}{x_{1t}^k}\right)^{-\theta_k'\upsilon_1} = \exp(\Delta\zeta_{it+1}'\delta_k + \Delta\xi_{it+1}) \left(\frac{x_{it+1}^k}{x_{it}^k}\right)^{-\theta_k'\upsilon_i} \tag{5}$$

where Δ is the first difference operator. Notice that this is true for the head and any other household member i.

Our preference specification (4) is a straightforward generalization of the commonly used Constant Elasticity of Substitution (CES) preferences; however, it differs importantly because these preferences yield demand systems which are (Gorman) aggregable over neither different goods nor different people. Where the usual CES preferences involve a constant elasticity of substitution between goods, either for a single person or across different household members, this specification is flexible enough to allow variable elasticities of substitution. Where CES preferences would imply that fixed expenditure shares of consumption would be allocated to different people and to different goods, the additional flexibility of allowing different curvature parameters means that efficient allocation will not generally give household members fixed consumption expenditures, as in the CES case; rather expenditure shares will vary with total household expenditures and with changes in the time-varying characteristics of household members.

4. Nutritional Investment

We now extend the model of Section 3 to 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 somewhat in the spirit of, say, Stiglitz (1976), or Dasgupta and Ray (1986). We have reason to believe that models in which nutrition may affect productivity are particularly salient, because using the same data (but looking across households, rather than within them) Foster and Rosenzweig (1994) find evidence that predictable variation in the returns to nutritional investment is correlated with caloric intake (for them, variation in returns comes from variation in the form of the labor contract).

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 no to depend on current activities and consumption.

Now the physical characteristics of household members are assumed to evolve in response to consumption according to a law of motion M, so that

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

Note that this law of motion permits consumption at time t to influence subsequent characteristics. 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.

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. $f(y|a,w)$. 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, even though that person's disutility from plowing may depend on those characteristics. Also note that the distribution of y depends not only on activities a, but also on observables w.

Formally, this is due to the fact that y does not depend directly on b but Z_i *does*. The new problem facing the household head requires her to take into account the influence of current consumption on future productivity:

$$(6)\quad H(p,x,b_1,\dots,b_n,w) = \max_{\{(c_i,a_i)\}_{i=1}^n} \sum_{i=1}^n \alpha_i \left(U(c_i,b_i) + Z_i(a_i,b_i)\right)$$
$$+\beta \int H\left(\hat{p}, \hat{p}' \sum_{i=1}^n y_i, \hat{b}_1,\dots,\hat{b}_n,\hat{w}\right) dG(\hat{p},y_1,\dots,y_n\hat{w}|p,a_1,\dots,a_n,w)$$

subject to the budget constraint

$$(7)\qquad p' \sum_{i=1}^n c_i \leq x$$

and the law of motion for physical characteristics

$$(8)\qquad \hat{b}_i = M(b_i,c_i).$$

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 (8).

Now consumption can affect not only utility but also future productivity. This changes the allocation problem facing the household head. Let $\mathrm{J}_{c^k}M$ denote the column of the Jacobian matrix of M corresponding to the partial derivatives of future characteristics with respect to consumption good k, and let $\mathrm{J}_{b_i}H$ denote the row of the Jacobian matrix of the value function H corresponding to the partial derivatives of H with respect to the vector of characteristics for person i. Then when the head gives consumption c_i^k to person i, the marginal benefit is not just the marginal utility $U_k(c_i,b_i)$ that appeared in (2), but also the returns to the nutritional investment: the marginal effect of consumption of good k on characteristics of i times the marginal returns to these characteristics.

Returns to nutritional investments are uncertain, so expected benefits are what matter. Let $R_i^k(p,x,b,w,a)$ denote the expected marginal benefit to an investment c^i_k of good k in person i, given the current state (p,x,b,w) and the activities $(a_1,\dots,a_n)$ undertaken by the household. Differentiating the second term of the Bellman equation (6) with respect to c^i_k gives

$$R^k_i(p,x,b_1,\dots,b_n,w,a_1,\dots,a_n) \equiv$$
$$\int \mathrm{J}_{b_i} H(\hat{p},\hat{p}'\sum_{j=1}^{n} y_i, M(b_1,c_1),\dots,M(b_n,c_n),\hat{w}) \mathrm{J}_{c^k} M(b_i,c_i) dG(\hat{p},y_1,\dots,y_n,\hat{w}|p,a_1,\dots,a_n,w).$$

Then first order conditions from the nutritional investment problem include

$$\alpha_i U_k(c_i,b_i) + \beta R^k_i(p,x,b,w,a) = \mu,$$

for $i = 1,\dots,n$ and $k = 1,\dots,K$, where μ is the Lagrange multiplier associated with the budget constraint (7). Though this expression resembles the conventional Euler equation which characterizes a consumer's investment decisions, it is not. In the conventional Euler equation the marginal benefit of consuming today is equated with the marginal opportunity cost of investing. Here both the terms on the left hand side are marginal benefits associated with consumption; the opportunity cost is that the consumption could have been given to some other person in the household, which is captured by the Lagrange multiplier μ.

Evaluating this expression at periods t and $t+1$ and for person i and for the head, it follows that in the nutritional investment model the counterpart to (2) is

$$\frac{\alpha_i U_k(c_{it+1},b_{it+1}) + \beta R^k_{it+1}}{\alpha_i U_k(c_{it},b_{it}) + \beta R^k_{it}} = \frac{U_k(c_{1t+1},b_{1t+1}) + \beta R^k_{1t+1}}{U_k(c_{1t},b_{1t}) + \beta R^k_{1t}}. \tag{9}$$

In our earlier model, changes in the head's marginal utility of consumption were perfectly correlated with changes in person i's marginal utility of consumption, and it was this (along with a parameterization of the utility function) that delivered the exclusion restrictions we used to test the earlier model: after controlling for marginal utility "shifters" such as age and health, earnings shouldn't affect the relationship between the marginal utilities of people within the household.

In the nutritional investment model our earlier exclusion restriction doesn't hold: consumption given to person i will depend on expected returns to nutritional investments, so that in this model we'd expect to observe a correlation between idiosyncratic consumption and earnings. However, other exclusion restrictions are implied by the model. Equation (9) implies that the consumption of person i will be related to the consumption of the head and the current values of the preference shifting characteristics b_i and b_1, as before, but will also depend on the variables that influence expectations of returns to nutritional investment, which are limited to contemporaneous values of (p,x,b,w,a) and their histories. In particular, *current* weather w may help to predict *future* weather and thus future returns, so that differences in current weather conditions can be expected to influence current consumption allocations. But after controlling for the predicted weather, actual realizations of future weather should *not* influence current consumption allocations, since the realizations simply aren't known at the time of the allocation.

5. Empirical Tests

We've presented two models of intra-household allocation. Both of these posit that allocations are dynamically efficient. In the first model consumption influences only utility, and efficiency requires that within the household the rate of change in marginal utility is equated across all household members; thus, first model is a simple dynamic household model with efficient allocation of food consumption exhibiting full risk sharing. In a model in which all household members had identical CRRA utility functions, this would imply that consumption growth rates would be identical within the household. However, because we allow marginal utilities of consumption to depend on time-varying individual characteristics and allow risk aversion to depend on fixed individual characteristics it may be efficient for consumption to change at different rates. For example, a more risk-averse individual would happily exchange a higher expected consumption for a less variable one. In this model observed differences in consumption growth rates are attributed either to differences in risk aversion, or to changes in individual characteristics which affect the marginal utility of food or nutrition.

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, changes in the allocation of energy and protein in the household may depend not only on differences in the curvature of the utility function or on changes in individual characteristics such as age, 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.

5.1. **Estimating the Intra-household Risk Sharing 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 (4) and if there's efficient risk sharing. In this case, consumption and expenditures depend on total household expenditures and individual preferences and characteristics. We can use (5) to estimate the relationship between the rate of changes of the head's consumption and the rate of change in others' consumption. Taking logs of (5) and rearranging yields the estimating equation

$$\Delta\log(x_{it}^k) = \Delta\log(x_{1t}^k)\frac{\theta_k'\upsilon_1}{\theta_k'\upsilon_i} + (\Delta\zeta_{it} - \Delta\zeta_{1t})'\frac{\delta_k}{\theta_k'\upsilon_i} + \frac{\Delta\xi_{it} - \Delta\xi_{1t}}{\theta_k'\upsilon_i}. \tag{10}$$

This relates the rate of growth in i's consumption of the kth consumption good to the rate of growth in the head's consumption, controlling for observable changes in characteristics such as (log) age and health (relative to the head). Unobservable preference shocks or other changes in individual characteristics (relative to the head) appear in the final term, and make up the disturbance term in the estimating equation. Consequently, we adopt the usual but important identifying assumption that unobserved time-varying characteristics are mean independent of the observed characteristics (υ_i, ζ_{it}) (i.e., that $\mathrm{E}(\xi_{it}|\zeta_{it}, \upsilon_i) = \mathrm{E}(\xi_{it})$).

It may be worth dwelling on the interpretation of (10). Note that there's no prediction regarding either the level of an individual's consumption or of his share, since both of these depend on the unobserved utility weights $\{\alpha_i\}$. Rather, (10) characterizes only the rate of changes in expenditures and consumption relative to the rate of change for the household head. Thus, this equation does not help understanding 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 rates of change in consumption relative to the head 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 (10). Alternatively, changes in the relative needs of different household members may result in changes in shares of food expenditures and nutrition relative to the head. For example, as a small boy matures, one would expect his share of household resources to increase, basically as a consequence of changes in the utility the boy derives from food consumption. Changes of this sort are captured by changes in ζ_{it}, and for the kth good depend on the vector of parameters δ_k.

Our attempts to estimate (10) are reported in Table 2. Here we exploit the relationship between ratios of direct and indirect utility given by (2) and (3) to estimate a system of three equations, each of the form of (10), 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 use a set of (per round) time effects (and no constant term); interactions between sex and the logarithm of age in years,[4] and between sex and the number of days sick in the most recent period; an indicator with the value of one if person i is in the second or third trimester of pregnancy; and a measure of lactation (the number of minutes spent nursing per day). For the fixed individual characteristics υ_i governing relative risk aversion ($\theta_k'\upsilon_i$), we've simply used gender. This gives us a specification in which the sex of person i is interacted with changes in the logarithm of the head's consumption as the leading terms on the right-hand side of the estimating equation. 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' food expenditures. Similarly, we use the entire basket of household food to calculate the total calories and protein from the household food basket, and use these household-level measures of nutrition as instruments for the heads' nutritional intakes. Results from this first-stage regression are shown in Table 5 in the Appendix. 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; results from this second-stage estimator are given in Table 6 in the Appendix. 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.

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). Because key variables on both the right and left hand sides of our estimating equation are expressed as changes in logs, the

[4]Since we're taking differences of the logarithm of ages the age variable should be thought of as changes in the proportionate ages of person i and the head.

	Food Exp.	Calories	Protein	F (p-value)	Food Exp.	Calories	Protein	F (p-value)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x^k_{1t} \times ♂$	1.6038*	1.4944*	1.6179*	1428.5493	1.6148*	1.5000*	1.6180*	1413.2552
	(0.0306)	(0.0408)	(0.0296)	(0.0000)	(0.0310)	(0.0411)	(0.0296)	(0.0000)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x^k_{1t} \times ♀$	1.0152*	1.1512*	1.0625*	781.9572	1.0031*	1.1568*	1.0670*	766.2346
	(0.0258)	(0.0391)	(0.0246)	(0.0000)	(0.0260)	(0.0392)	(0.0247)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times ♂$	0.4148*	0.3330	0.4452*	4.8577	0.4653*	0.3719*	0.4549*	4.9419
	(0.1346)	(0.1819)	(0.1446)	(0.0022)	(0.1358)	(0.1835)	(0.1455)	(0.0020)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times ♀$	0.1814	0.0398	0.0670	0.6086	0.2010	0.0555	0.0684	0.7474
	(0.1559)	(0.2108)	(0.1675)	(0.6093)	(0.1563)	(0.2116)	(0.1677)	(0.5237)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times ♂$	0.0048	0.0078	0.0052	1.2738	0.0047	0.0077	0.0051	1.2421
	(0.0032)	(0.0043)	(0.0034)	(0.2814)	(0.0032)	(0.0043)	(0.0034)	(0.2926)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times ♀$	−0.0038	−0.0058	−0.0096*	3.6258	−0.0042	−0.0060	−0.0096*	3.3356
	(0.0040)	(0.0054)	(0.0043)	(0.0124)	(0.0040)	(0.0054)	(0.0043)	(0.0185)
Pregnant	−0.1676*	−0.2411*	−0.1847*	1.7809	−0.1668*	−0.2488*	−0.1833*	1.8456
	(0.0835)	(0.1130)	(0.0898)	(0.1484)	(0.0838)	(0.1135)	(0.0899)	(0.1365)
Nursing	−0.0098	−0.0132	−0.0092	0.4182	−0.0095	−0.0129	−0.0094	0.3747
	(0.0102)	(0.0138)	(0.0109)	(0.7399)	(0.0102)	(0.0138)	(0.0109)	(0.7713)
Second quarter	0.0749*	0.1409*	0.1071*	8.7307	0.0648*	0.1305*	0.0911*	6.1360
	(0.0208)	(0.0279)	(0.0221)	(0.0000)	(0.0227)	(0.0305)	(0.0242)	(0.0004)
Third quarter	0.0128	0.1056*	0.1086*	14.0427	0.0283	0.1162*	0.1045*	7.7453
	(0.0209)	(0.0283)	(0.0225)	(0.0000)	(0.0237)	(0.0321)	(0.0254)	(0.0000)
Fourth quarter	0.0836*	0.0125	−0.0162	15.6535	0.0722*	0.0096	−0.0030	5.0024
	(0.0213)	(0.0281)	(0.0224)	(0.0000)	(0.0285)	(0.0381)	(0.0303)	(0.0018)
Δy^p_{1t+1}	—	—	—	—	0.1632	0.0619	−0.2186	2.4632
	—	—	—	—	(0.2757)	(0.3709)	(0.2940)	(0.0605)
Δy^u_{1t+1}	—	—	—	—	−0.0089	−0.0140	0.0309	4.9312
	—	—	—	—	(0.0260)	(0.0352)	(0.0279)	(0.0020)
Δy^p_{it+1}	—	—	—	—	−0.7757*	−0.6427	−0.2094	6.9830
	—	—	—	—	(0.2654)	(0.3563)	(0.2823)	(0.0001)
Δy^u_{it+1}	—	—	—	—	0.0404	−0.0640	−0.0340	3.9608
	—	—	—	—	(0.0297)	(0.0402)	(0.0319)	(0.0078)

TABLE 2. Expenditures & nutritional intakes within the household. Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. Point estimates may be interpreted as changes in person i's share of household food expenditures/calories/protein relative to the share of the female household head. Figures in parentheses are standard errors.

corresponding coefficients can be interpreted as elasticities. For example, we find a large difference in elasticities for males and females: for males in the household, the results show that individual food expenditures increase at a rate 50–60% more than the female household head (60% more for total food expenditures, 49% more for calories, and 62% more for protein). In sharp contrast, for other females in the household, the elasticities are not much greater than one (increasing at a rate 1.5% greater for expenditures, 15.1% for calories, and 6.25% greater for protein).

To interpret these changes, consider that 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,[5] Since in fact these coefficients are all much greater than one for males, on a strict interpretation of (10) this implies that males are considerably less averse to risk than are other household members, and bear a disproportionate amount of the aggregate risk faced by the household. Further, males' tolerance of variation in the consumption of calories is less than their tolerance of variation in either expenditures or protein (relative to the household head), suggesting that when the household faces an adverse shock, males substitute toward less expensive sources of calories to a greater extent than do females.

As with risk attitudes, (log) age has a very different influence on consumption across sexes. On average a one percent increase in the ratio of a male's age to head's age results in a 0.41 per cent increase in the value of food consumed by that male, a corresponding 0.33 per cent increase in calories and a 0.45 per cent increase in protein intake, increases that are jointly highly significant. For females the point estimates suggest that age increases consumption relative to the head, but none of the point estimates are either individually or jointly significantly different from zero. Accordingly, males not only bear the largest share of risk in the household, but also assume additional risk as they age at much a greater rate than do females.

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. Sickness has no significant effect on male's consumption relative to the household head. Sickness causes

[5]And if these coefficients were equal, individual expenditure shares would be constant (controlling for individual characteristics), and we could use a test of risk-sharing similar to the test of Townsend (1994), with household expenditure aggregates on the right-hand-side of the equation, instead of just the expenditures of the household head. But because these coefficients are significantly (and dramatically) different across males and females, this sort of aggregation in our case would be an evident mis-specification.

females to have a (jointly) significant decrease in consumption, but of apparently small magnitude. Surprisingly, being pregnant appears to result in a larger fall in women's food expenditures, calories, and protein than does being sick but these effects, though large and individually significant, are not jointly statistically significant.[6]

One of the important benefits of our structural model is that it gives us easily interpretable parameter estimates. And within the class of structurally estimated preferences we have an unusually rich parameterization, which allows for a great deal of heterogeneity (often a weakness of structural approaches to estimation). Neverthless, if the preferences we give in (4) are mis-specified, our results will be unreliable, even if there's full risk-sharing within these households.[7]

5.2. **Testing Full Risk Sharing Within the Household.** 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 (2), that is that full risk sharing is achieved. In this case, the residuals from (10) will be orthogonal to all other information, shocks, and other outcomes which might affect the household or its individual members. In particular, surprises in individual labor earnings ought not to have any effect on the consumption allocation rule provided by (10).

To test this, we construct predictions of labor earnings for different individuals, and then to use these to construct measures of unpredicted earnings shocks. 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

[6]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 relative to the head, 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.

[7]We've tested our specification of utility by projecting the residuals on different functions of variables which are assumed to be exogeneous. These tests provide evidence that ζ_{it} ought to include squared terms for male age and male sickness. However, adding these higher order terms complicates the interpretations of age and sickness without appreciably changing any of our other estimated parameters, so we've consigned estimates of the more complicated specification to Table 7 in the Appendix.

(and squares of these last three quantities); next are month and village specific observations and predictions of weather (because of seasons, a large component of weather changes is indeed easy to forecast).

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 in a log-earnings regression. By themselves, these predicted weather variables explain eleven per cent of observed variation in log earnings.

When we use only predicted weather interacted with village dummies, predicted earnings can only vary across time and villages. The variation we'd like to have is in earnings across individuals within a household. Accordingly, we also interact predicted weather with individual characteristics. These interactions are important: when we add them, the proportion of variance in log earnings that we can explain doubles, giving us an R^2 of 22 per cent. Education, age, and sex all are important for determining earnings; physical characteristics less so (none is individually significant in the predicted earnings regression).

We use the predicted earnings regression to construct predicted earnings y^p_{it+1} and 'unpredicted' earnings y^u_{it+1}, computed as the forecast error in the predicted earnings regression. Both predicted and unpredicted earnings variables vary across both time and people. We then add the change in the earnings variables for both person i and the household head to the base regression (10). 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 earnings shocks for the head, and both predicted and unpredicted individual earnings shocks have a (jointly) significant effect on consumption.

Our results amount to a firm rejection of the null hypothesis that changes in earnings are orthogonal to changes in consumption. However, the pattern of results suggests another puzzle, as the patterns of signs associated with the earnings variables vary in surprising ways. In particular, a one peso increase in person i's unpredicted earnings leads to an estimated 4 percent increase in *i*'s food expenditures relative to the head,[8] but if anything appears to have a *negative* effect on nutrition. Related, the effect of surprises in the heads' earnings, though jointly significantly different from zero also have disparate signs, with apparent decreases in expenditures and calories, and an apparent increase in protein.

Predictable increases in earnings lead to a quite large and significant decrease in one's expenditures, as well as large (but not individually significant) decreases in calories and protein. In particular, we estimate that a one peso increase in predicted earnings leads to a 78 percent decrease in food expenditures, a 64 percent decrease in calories, and a 21 percent decrease in the share of protein, all relative to the head's consumption expenditures, calories, and protein respectively.

We are surprised by the result that consumption responds differently to predictable and unpredictable earnings shocks, not only because it leads us to reject our null hypothesis of full risk-sharing, but because it seems to rule out many plausible alternative models as well. Conditional at least on utility being separable between consumption and activities, many alternative models would predict a positive correlation between individual earnings and consumption (e.g., the household bargaining models of McElroy or the collective models of Chiappori).

One possibility is, of course, that utility *isn't* separable between consumption and activities. For example, if leisure and consumption were complements, then household members who worked harder (and earned more) might also consume less. But while *predictable* increases in earnings have a large, negative effect on own consumption, *unpredictable* increases have a positive effect. Simply assuming a complementarity between leisure and consumption can't explain why the effects of predictable and unpredictable earnings shocks should be different.

Beyond the specific possibility that leisure and consumption may not be separable in utility, our test of full risk-sharing also relies more generally on the assumption that variation in earnings is unrelated to differences across household members in changes in unobserved characteristics that effect consumption allocations. Here it may be worth comparing our estimation strategy to the approach one might take in a more 'reduced-form' exercise. "Double differencing" is a common strategy for dealing with unobserved variation; in this setting the hope would be that by differencing over time one could eliminate unobservable individual-specific fixed effects

[8] Average daily food expenditures per individual are about 6 pesos, so a one peso increase in earnings is consequential.

which might influence consumption, while by differencing across individuals within the household that one could eliminate any time-varying unobservable factors which operate at the level of the household. But in effect this what we do. Our estimating equation differences over time explicitly, and across individuals within a household implicitly (by making everything relative to the household head).

The real difference between our approach and something less structural is the guidance our model gives us in specifying the functional form of the estimating equation (so that it's in logarithms rather than levels, for example), and that coefficients from our estimation are interpretable as being parameters of a system of demands. The theory also tells us something about ways in which a possible mis-specification of preferences *won't* affect our test. For example, differences in discount factors either across or within households won't have any effect on our test; neither would unobserved differences in demand shifters for different goods over individuals or time (such differences would appear in the A_i^k or B_t^k terms in (4)).

5.3. **Testing the Nutritional Investment Model.** We've argued that the fact that predictable and unpredictable shocks have different effects on intrahousehold allocation is difficult to explain using a model like that offered in Section 3, even if one allows for the possibility that we've mis-specicified preferences.

However, we've also offered an alternative model, which has the property that the household may make investments in the nutrition of members when the predicted marginal return to those investments is high.

In particular, as discussed in Section 3, we use the consumption expenditures by food categories to implement the same tests.[9], and see how shocks to earnings affect different of these food categories. The key to this test is to note that if nutritional investment is driving changes in consumption, then predicted or realized changes in returns to nutritional investment 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 (we do not observe returns to nutritional investment directly, but these will affect individual earnings, which we do observe). However, if 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

[9]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)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x^k_{1t} \times$ ♂	1.2287*	1.2498*	1.3484*	1.4999*	1.2036*	1.3690*	1.4421*	1960.8081
	(0.0200)	(0.0210)	(0.0319)	(0.0335)	(0.0283)	(0.0327)	(0.0310)	(0.0000)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x^k_{1t} \times$ ♀	0.7688*	0.7578*	0.9235*	0.9143*	0.6536*	0.7779*	0.8984*	860.7171
	(0.0208)	(0.0204)	(0.0317)	(0.0291)	(0.0238)	(0.0289)	(0.0260)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times$ ♂	0.0672	0.0693	−0.0224	0.3243	0.3240*	0.0464	0.1557	2.4428
	(0.1161)	(0.1138)	(0.1042)	(0.1748)	(0.1013)	(0.1261)	(0.1187)	(0.0168)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times$ ♀	0.1045	0.0608	0.0104	0.0686	0.0707	0.0265	0.0389	0.3343
	(0.1346)	(0.1318)	(0.1207)	(0.2025)	(0.1175)	(0.1464)	(0.1373)	(0.9386)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times$ ♂	0.0048	−0.0022	−0.0064*	0.0101*	−0.0081*	0.0039	−0.0041	3.6502
	(0.0027)	(0.0027)	(0.0025)	(0.0041)	(0.0024)	(0.0030)	(0.0028)	(0.0006)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times$ ♀	0.0008	−0.0033	−0.0033	−0.0082	−0.0041	0.0042	0.0046	1.4864
	(0.0034)	(0.0034)	(0.0031)	(0.0052)	(0.0030)	(0.0037)	(0.0035)	(0.1668)
Pregnant	−0.1394	0.0378	0.0011	−0.1611	−0.0179	−0.0254	−0.0336	0.8679
	(0.0722)	(0.0707)	(0.0647)	(0.1085)	(0.0627)	(0.0783)	(0.0736)	(0.5310)
Nursing	0.0068	−0.0126	−0.0042	0.0025	0.0057	−0.0058	−0.0056	0.6336
	(0.0088)	(0.0086)	(0.0079)	(0.0132)	(0.0076)	(0.0095)	(0.0090)	(0.7285)
Second quarter	−0.0461*	0.0794*	0.0185	−0.0254	0.1337*	0.0185	0.0256	11.9649
	(0.0176)	(0.0173)	(0.0159)	(0.0266)	(0.0167)	(0.0194)	(0.0181)	(0.0000)
Third quarter	−0.0029	−0.0074	0.0267	0.0502	0.0089	−0.0380	−0.0101	1.7347
	(0.0179)	(0.0176)	(0.0161)	(0.0270)	(0.0156)	(0.0195)	(0.0184)	(0.0960)
Fourth quarter	0.0720*	−0.0073	−0.0031	0.0141	0.0096	0.0522*	0.0025	4.1328
	(0.0182)	(0.0175)	(0.0161)	(0.0270)	(0.0156)	(0.0196)	(0.0184)	(0.0001)

TABLE 3. Expenditure shares for different food groups within the household. Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. 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)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times$ ♂	1.2273*	1.2488*	1.3494*	1.4975*	1.1985*	1.3687*	1.4465*	1958.7733
	(0.0199)	(0.0210)	(0.0319)	(0.0334)	(0.0282)	(0.0327)	(0.0311)	(0.0000)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times$ ♀	0.7685*	0.7589*	0.9222*	0.9133*	0.6547*	0.7776*	0.8940*	859.1147
	(0.0207)	(0.0203)	(0.0317)	(0.0290)	(0.0237)	(0.0289)	(0.0261)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times$ ♂	0.0563	0.0910	−0.0112	0.3182	0.3066*	0.0499	0.2041	2.3978
	(0.1166)	(0.1143)	(0.1047)	(0.1755)	(0.1016)	(0.1269)	(0.1196)	(0.0189)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times$ ♀	0.0989	0.0697	0.0187	0.0624	0.0670	0.0284	0.0634	0.3544
	(0.1345)	(0.1318)	(0.1208)	(0.2024)	(0.1172)	(0.1465)	(0.1375)	(0.9285)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times$ ♂	0.0047	−0.0022	−0.0063*	0.0099*	−0.0080*	0.0039	−0.0041	3.5381
	(0.0027)	(0.0027)	(0.0025)	(0.0041)	(0.0024)	(0.0030)	(0.0028)	(0.0008)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times$ ♀	0.0008	−0.0033	−0.0035	−0.0081	−0.0040	0.0041	0.0041	1.4179
	(0.0034)	(0.0034)	(0.0031)	(0.0052)	(0.0030)	(0.0037)	(0.0035)	(0.1929)
Pregnant	−0.1340	0.0350	−0.0053	−0.1490	−0.0262	−0.0214	−0.0384	0.8171
	(0.0721)	(0.0707)	(0.0648)	(0.1085)	(0.0626)	(0.0784)	(0.0737)	(0.5729)
Nursing	0.0064	−0.0124	−0.0036	0.0019	0.0058	−0.0057	−0.0047	0.5960
	(0.0088)	(0.0086)	(0.0079)	(0.0132)	(0.0076)	(0.0095)	(0.0090)	(0.7598)
Second quarter	−0.0632*	0.0820*	0.0381*	−0.0452	0.1396*	0.0191	0.0344	11.8320
	(0.0192)	(0.0189)	(0.0174)	(0.0290)	(0.0179)	(0.0212)	(0.0198)	(0.0000)
Third quarter	−0.0193	0.0054	0.0425*	0.0387	0.0027	−0.0351	0.0160	1.6831
	(0.0203)	(0.0199)	(0.0182)	(0.0305)	(0.0176)	(0.0221)	(0.0208)	(0.1080)
Fourth quarter	0.1022*	−0.0253	−0.0313	0.0346	0.0168	0.0471	−0.0314	3.9598
	(0.0244)	(0.0238)	(0.0218)	(0.0365)	(0.0211)	(0.0264)	(0.0248)	(0.0002)
Δy^p_{1t+1}	−0.4689*	0.2663	0.4538*	−0.3725	−0.0590	0.0565	0.5270*	1.9934
	(0.2359)	(0.2314)	(0.2117)	(0.3550)	(0.2047)	(0.2565)	(0.2414)	(0.0520)
Δy^u_{1t+1}	0.0096	0.0061	−0.0450*	0.0640	−0.0371	0.0061	−0.0456*	2.0214
	(0.0224)	(0.0219)	(0.0201)	(0.0337)	(0.0194)	(0.0243)	(0.0229)	(0.0486)
Δy^p_{it+1}	0.2376	−0.4189	−0.1532	0.0310	0.3302	−0.0640	−0.7497*	2.7966
	(0.2264)	(0.2221)	(0.2031)	(0.3406)	(0.1965)	(0.2461)	(0.2321)	(0.0066)
Δy^u_{it+1}	0.0708*	−0.0592*	−0.0052	0.0399	−0.0319	0.0376	0.0152	1.7887
	(0.0256)	(0.0251)	(0.0229)	(0.0385)	(0.0222)	(0.0278)	(0.0262)	(0.0847)

TABLE 4. Expenditure shares for different food groups within the household. Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. 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.

protein in response to increases in earnings, but *not* necessarily in costlier categories of food which are superior in terms of utility.

Following this logic, we reorganize food expenditures into groups according to type, rather than nutrients. These groups include rice, corn, other staples, meat and fish, vegetables, snacks and fruit, and a residual "other" category. Basic results from our specification for the model without nutritional investment appear in the left-hand panel of Table 3.

Because all our dependent variables in this specification are expenditures, the estimated coefficients associated with the change in the logarithm of the head's expenditures can be interpreted as the elasticity of expenditures with respect to the head's expenditures. Then the expenditure elasticity of individual demand for these food groups shows the same division by gender that we observed for total expenditures and nutrition. The expenditure elasticities for males with respect to the head's expenditures range from 1.20 for vegetables to 1.50 for meat (all are significantly greater than one), while expenditure elasticities for other females in the household range from 0.65 for vegetables to 0.92 for "other staples" (all are significantly less than one). However, unlike total expenditures, expenditures for most food groups do not increase sharply with age for males. Only for vegetables do we see large and statistically significant increases in expenditure, a result consistent with a mounting body of evidence that children don't like to eat their vegetables (Blanchette and Brug, 2005).

Sickness had no significant effect on total expenditure or nutrition for males, but perhaps these were masked by compositional changes in diet as we do see significant effects across different food groups for males. In particular, there's some evidence of substitution away from corn (the main staple), "other staples", and vegetables toward rice, meat, and snacks, a finding which may suggest some "coddling" of sick males. In contrast, though sickness leads females to consume a smaller share of protein, it has no significant effect on expenditures for any given food group. Neither do pregnancy or nursing lead to significant changes in any food expenditure group.

In Table 4 we add earnings changes to the base specification (as with Table 2), and find additional evidence against within-household full risk sharing. Increases in the head's predicted earnings or a decrease in i's predicted earnings both lead to a decrease in person i's expenditures on rice (the preferred staple) relative to the head, but an increase in i's share of other less desirable staples and "Other". Thus changes in one person's expected earnings lead to rather large compositional changes in diet, even when the overall effects on nutrition are more modest.

The magnitude of the estimated effects of unpredicted changes to earnings are generally much smaller than are the effects associated with predicted changes, but are also often statistically significant. Unpredicted changes to head's earnings result in significant decreases in i's expenditures on "Other Staples" or "Other", while unpredicted changes to i's own earnings lead to a significant shift in expenditure away from corn and toward rice.

Overall, one can see that changes in earnings lead to changes in the composition of diet, perhaps particularly between less-desirable (corn and "other staples") and more-desirable (rice and meat). These changes pose a challenge to the hypothesis of full risk sharing, even when one allows for the possibility of nutritional investments. Though our formulation of preferences allows demand for different sorts of food to vary with various time-varying observables, risk sharing within the household should rule out variation in diet (either in quantities or composition) in response to earnings shocks.

6. Conclusion

In this paper we've constructed a direct test of the hypothesis of full risk sharing in food consumption within the household in the Bukidnon region of the Philippines. Our test allows for a flexible specification of preferences, with variation in risk aversion across individuals and which also allows us to control for other observable individual characteristics. We reject the full risk sharing hypothesis, as the allocation of food expenditures, calories, and protein seems to depend on the realization of individuals' off-farm earnings.

In contrast to other tests of risk sharing, we also investigate the possibility that dynamic effects related to the productivity of nutritional investments in individuals may affect the allocation of food within the household. Accordingly, 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 workers' productivity. Then predictable variation in returns to nutronal investment could account for variation in the intra-household allocation of food.

We find that indeed perfectly predictable variation in individual earnings turns out to significantly affect expenditures and nutrition, consistent with the hypothesis of nutritional investment. But at the same time, unpredictable shocks to individual earnings tend to lead to increases in total food expenditure, but *decreases* in calories and protein intakes. Earnings shocks also lead to changes in the composition of diet, in what we interpret as shifts between more and less desirable types of food. We're left with strong evidence against the hypothesis of full intra-household risk-sharing, whether or not there's nutritional investment.

REFERENCES

Angelucci, M. and G. De Giorgi (2009). Indirect effects of an aid program: How do cash transfers affect ineligibles' consumption? *The American Economic Review 99*(1), 486–508.

Becker, G. S. (1974). A theory of social interactions. *Journal of Political Economy 82*, 1063–1094.

Blanchette, L. and J. Brug (2005). Determinants of fruit and vegetable consumption among 6–12-year-old children and effective interventions to increase consumption. *Journal of Human Nutrition and Dietetics 18*(6), 431–443.

Blundell, R., M. Browning, and C. Meghir (1994). Consumer demand and the life-cycle allocation of household expenditures. *Review of Economic Studies 61*, 57–80.

Bobonis, G. (2009). Is the allocation of resources within the household efficient? new evidence from a randomized experiment. *Journal of Political Economy 117*(3), 453–503.

Bouis, H. E. and L. Haddad (1990). *Agricultural commercialization, nutrition, and the rural poor: a study of Philippine farm households*. Boulder: Lynne Rienner Publishers.

Bourguignon, F., M. Browning, and P. A. Chiappori (2009). Efficient intrahousehold allocations and distribution factors: Implications and identification. *Review of Economic Studies 76*(2), 503–528.

Bourguignon, F. and P.-A. Chiappori (1992). Collective models of household behavior. *European Economic Review 36*, 355–364.

Browning, M., F. Bourguignon, P.-A. Chiappori, and V. Lechene (1994). Income and outcomes: A structural model of intrahousehold allocation. *The Journal of Political Economy 102*(6), 1067–1096.

Browning, M. and P. Chiappori (1998). Efficient intra-household allocations: A general characterization and empirical tests. *Econometrica 66*(6), 1241–1278.

Chiappori, P.-A. (1988). Rational household labor supply. *Econometrica 56*(1), 63–90.

Chiappori, P.-A. (1992). Collective labor supply and welfare. *Journal of Political Economy 100*(3), 437–67.

Dasgupta, P. and D. Ray (1986). Inequality as a determinant of malnutrition and unemployment: Theory. *Economic Journal 96*, 1011–1034.

Dercon, S. and P. Krishnan (2000). In sickness and in health: Risk sharing within households in rural Ethiopia. *Journal of Political Economy 108*(4), 688–727.

Dubois, P. (2000). Assurance complète, hétérogénéité de préférences et mètayage du Pakistan. *Annales d'Economie et de Statistique 59*, 1–36.

Eder, J. (2006). Gender and household economic planning in the rural Philippines. *Journal of Southeast Asian Studies 37*(3), 397–413.

Foster, A. and M. Rosenzweig (1994). A test for moral hazard in the labor market: Contractual arrangements, effort, and health. *The Review of Economics and Statistics LXXVI*(2), 213–227.

Illo, J. F. (1995). Who heads the household? Women in households in the Philippines. In A. T. Torres (Ed.), *The Filipino woman in focus: A book of readings*, pp. 235–54. Quezon City: Ateneo de Manila University Press.

Jacoby, H. (2002). Is there an intrahousehold "flypaper effect"? evidence from a school feeding programme. *Economic Journal 112*(476), 196–221.

Jalan, J. and M. Ravallion (1999). Are the poor less well insured? evidence on vulnerability to income risk in rural China. *Journal of Development Economics 58*, 61–81.

Lundberg, S. J., R. A. Pollak, and T. J. Wales (1997). Do husbands and wives pool their resources? *The Journal of Human Resources XXXII*(3), 462–480.

Mace, B. J. (1991). Full insurance in the presence of aggregate uncertainty. *Journal of Political Economy 99*, 928–956.

Mazzocco, M. (2007). Household inter-temporal behavior: A collective characterization and a test of commitment. *Review of Economic Studies 74*(3), 857–895.

Mazzocco, M. and S. Saini (2011). Testing efficient risk sharing with heterogeneous risk preferences. *American Economic Review Forthcoming*.

Pitt, M. M. and M. R. Rosenzweig (1985). Health and nutrient consumption across and within farm households. *The Review of Economics and Statistics 67*(2), 212–223.

Pitt, M. M., M. R. Rosenzweig, and M. N. Hassan (1990). Productivity, health, and inequality in the intrahousehold distribution of food in low-income countries. *The American Economic Review 80*(5), 1139–1156.

Robb, A. L., L. Magee, and J. B. Burbidge (1992). Kernel smoothed consumption-age quantiles. *The Canadian Journal of Economics 25*(3), 669–680.

Stiglitz, J. (1976). The efficiency wage hypothesis, surplus labor and the distribution of income in L.D.C's. *Oxford Economic Papers 28*, 185–207.

Thomas, D. (1990). Intra-household resource allocation: An inferential approach. *Journal of Human Resources 25*, 635–64.

Townsend, R. M. (1994, May). Risk and insurance in village India. *Econometrica 62*(3), 539–591.

Udry, C. (1994). Risk and insurance in a rural credit market: An empirical investigation in northern Nigeria. *Review of Economic Studies 63*, 495–526.

Udry, C. (1996). Gender, agricultural production, and the theory of the household. *Journal of Political Economy 104*(5), 1010–1046.

World Health Organization (1985). Energy and protein requirements. WHO Technical Report Series 724, Geneva.

APPENDIX A. SUPPORTING TABLES

	Food Exp.	Calories	Protein	F (p-value)	Food Exp.	Calories	Protein	F (p-value)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x_{1t}^k \times$ ♂	0.5555*	0.6482*	0.5909*	1120.0657	0.0016	−0.0071	−0.0032	0.1300
	(0.0263)	(0.0386)	(0.0353)	(0.0000)	(0.0264)	(0.0387)	(0.0353)	(0.9423)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta \log x_{1t}^k \times$ ♀	−0.0181	−0.0137	−0.0153	0.5605	0.8064*	0.8986*	0.9133*	3808.7684
	(0.0322)	(0.0507)	(0.0449)	(0.6410)	(0.0323)	(0.0507)	(0.0450)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times$ ♂	−0.0941	−0.0458	−0.0499	0.6550	−0.0073	0.0110	−0.0003	0.0215
	(0.1509)	(0.1509)	(0.1509)	(0.5797)	(0.1519)	(0.1518)	(0.1518)	(0.9957)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Age} \times$ ♀	0.0532	0.1076	0.0821	0.7680	−0.1633	−0.0287	−0.0518	2.7806
	(0.1749)	(0.1748)	(0.1748)	(0.5118)	(0.1751)	(0.1750)	(0.1750)	(0.0395)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times$ ♂	−0.0037	−0.0059	−0.0047	6.0762	0.0001	0.0000	0.0001	0.0021
	(0.0036)	(0.0036)	(0.0036)	(0.0004)	(0.0036)	(0.0036)	(0.0036)	(0.9999)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta \log \text{Days sick} \times$ ♀	−0.0005	−0.0001	0.0001	0.0161	0.0037	0.0042	0.0062	9.8154
	(0.0045)	(0.0045)	(0.0045)	(0.9972)	(0.0045)	(0.0045)	(0.0045)	(0.0000)
Pregnant	0.0078	0.0131	0.0076	0.0369	0.0729	0.1702	0.1170	15.3829
	(0.0938)	(0.0937)	(0.0937)	(0.9905)	(0.0940)	(0.0939)	(0.0938)	(0.0000)
Nursing	0.0008	0.0004	0.0000	0.0068	0.0001	0.0063	0.0032	1.0874
	(0.0114)	(0.0114)	(0.0114)	(0.9992)	(0.0114)	(0.0114)	(0.0114)	(0.3530)
Second quarter	−0.0302	−0.0506*	−0.0397	10.4082	0.0073	−0.0147	−0.0009	1.1949
	(0.0234)	(0.0231)	(0.0232)	(0.0000)	(0.0255)	(0.0252)	(0.0253)	(0.3100)
Third quarter	0.0202	−0.0427	−0.0438	8.3790	−0.0016	−0.0239	−0.0185	3.6834
	(0.0235)	(0.0234)	(0.0235)	(0.0000)	(0.0266)	(0.0265)	(0.0265)	(0.0115)
Fourth quarter	−0.0602*	−0.0083	0.0151	7.7217	−0.0010	0.0168	0.0112	1.1602
	(0.0238)	(0.0233)	(0.0235)	(0.0000)	(0.0320)	(0.0316)	(0.0317)	(0.3233)
y_{1t+1}^p	—	—	—	—	0.0619	−0.1050	−0.0665	0.5773
	—	—	—	—	(0.3085)	(0.3068)	(0.3069)	(0.6299)
y_{1t+1}^u	—	—	—	—	0.0097	0.0070	0.0025	0.5024
	—	—	—	—	(0.0291)	(0.0291)	(0.0291)	(0.6806)
y_{it+1}^p	—	—	—	—	0.0087	0.1792	0.1177	1.5005
	—	—	—	—	(0.2967)	(0.2944)	(0.2947)	(0.2122)
y_{it+1}^u	—	—	—	—	−0.0092	−0.0060	−0.0063	0.4078
	—	—	—	—	(0.0333)	(0.0333)	(0.0333)	(0.7474)

TABLE 5. 'First stage' regression of heads' consumption (interacted with sex) on household expenditures (also interacted with sex). Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. Point estimates may be interpreted as the elasticity of the head's consumption expenditures and nutrition with respect to household level expenditures. Figures in parentheses are SUR standard errors.

	Food Exp.	Calories	Protein	F (p-value)	Food Exp.	Calories	Protein	F (p-value)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times ♂$	1.5923*	1.4110*	1.5699*	806.4525	1.6163*	1.5129*	1.6329*	1413.3903
	(0.0473)	(0.0596)	(0.0597)	(0.0000)	(0.0312)	(0.0412)	(0.0299)	(0.0000)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times ♀$	1.0181*	1.0378*	1.0313*	484.9057	1.0544*	1.1956*	1.1414*	852.3845
	(0.0398)	(0.0562)	(0.0491)	(0.0000)	(0.0266)	(0.0403)	(0.0258)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♂$	0.4128*	0.3334*	0.4439*	7.0925	0.4585*	0.3712*	0.4534*	4.7528
	(0.1511)	(0.1510)	(0.1509)	(0.0001)	(0.1364)	(0.1858)	(0.1477)	(0.0026)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♀$	0.1832	0.0488	0.0745	0.4581	0.2020	0.0557	0.0667	0.7602
	(0.1749)	(0.1751)	(0.1750)	(0.7116)	(0.1571)	(0.2143)	(0.1703)	(0.5163)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♂$	0.0048	0.0073*	0.0050	2.6652	0.0048	0.0078	0.0051	1.2433
	(0.0036)	(0.0036)	(0.0036)	(0.0461)	(0.0032)	(0.0044)	(0.0035)	(0.2922)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♀$	−0.0038	−0.0054	−0.0094*	2.2580	−0.0044	−0.0061	−0.0099*	3.5625
	(0.0045)	(0.0045)	(0.0045)	(0.0795)	(0.0040)	(0.0055)	(0.0043)	(0.0136)
Pregnant	−0.1671	−0.2259*	−0.1818	4.3004	−0.1634	−0.2537*	−0.1889*	1.8163
	(0.0937)	(0.0939)	(0.0937)	(0.0049)	(0.0842)	(0.1149)	(0.0913)	(0.1418)
Nursing	−0.0098	−0.0135	−0.0092	0.9404	−0.0093	−0.0128	−0.0092	0.3624
	(0.0114)	(0.0114)	(0.0114)	(0.4200)	(0.0103)	(0.0140)	(0.0111)	(0.7802)
Second quarter	0.0738*	0.1275*	0.1012*	19.1792	0.0676*	0.1333*	0.0956*	6.2618
	(0.0237)	(0.0238)	(0.0237)	(0.0000)	(0.0229)	(0.0309)	(0.0245)	(0.0003)
Third quarter	0.0134	0.0943*	0.1032*	11.6579	0.0244	0.1191*	0.1102*	9.0100
	(0.0236)	(0.0239)	(0.0239)	(0.0000)	(0.0238)	(0.0325)	(0.0258)	(0.0000)
Fourth quarter	0.0822*	0.0166	−0.0120	4.0974	0.0788*	0.0083	−0.0082	6.5683
	(0.0244)	(0.0233)	(0.0236)	(0.0065)	(0.0286)	(0.0386)	(0.0308)	(0.0002)
y^p_{1t+1}	—	—	—	—	0.1272	0.0650	−0.2044	2.0309
	—	—	—	—	(0.2771)	(0.3754)	(0.2985)	(0.1072)
y^u_{1t+1}	—	—	—	—	−0.0095	−0.0142	0.0316	5.0996
	—	—	—	—	(0.0261)	(0.0356)	(0.0283)	(0.0016)
y^p_{it+1}	—	—	—	—	−0.7395*	−0.6584	−0.2415	6.0267
	—	—	—	—	(0.2668)	(0.3607)	(0.2866)	(0.0004)
y^u_{it+1}	—	—	—	—	0.0401	−0.0647	−0.0350	3.9409
	—	—	—	—	(0.0299)	(0.0407)	(0.0324)	(0.0080)

TABLE 6. ‘Second stage’ regression, using household expenditures interacted with sex as instruments. Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. Point estimates may be interpreted as the elasticity of the head’s consumption expenditures and nutrition with respect to household level expenditures. Figures in parentheses are SUR standard errors.

	Food Exp.	Calories	Protein	F (p-value)	Food Exp.	Calories	Protein	F (p-value)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times ♂$	1.6051*	1.5017*	1.6270*	1430.4151	1.6160*	1.5068*	1.6274*	1415.6066
	(0.0306)	(0.0411)	(0.0298)	(0.0000)	(0.0310)	(0.0413)	(0.0298)	(0.0000)
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: $\Delta\log x^k_{1t} \times ♀$	1.0148*	1.1452*	1.0610*	778.0939	1.0024*	1.1503*	1.0651*	761.9604
	(0.0258)	(0.0391)	(0.0247)	(0.0000)	(0.0260)	(0.0392)	(0.0247)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♂$	0.0120	−1.2512*	−0.9525*	7.1196	0.0933	−1.1988*	−0.9539*	7.9345
	(0.2843)	(0.3856)	(0.3062)	(0.0001)	(0.2863)	(0.3882)	(0.3077)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♂^2$	0.8441	3.3016*	2.9315*	11.9923	0.7770	3.2631*	2.9459*	12.5696
	(0.5309)	(0.7211)	(0.5719)	(0.0000)	(0.5327)	(0.7238)	(0.5728)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♀$	0.0582	−0.3610	−0.1513	0.4978	0.1002	−0.3419	−0.1722	0.5285
	(0.3247)	(0.4387)	(0.3493)	(0.6838)	(0.3261)	(0.4407)	(0.3501)	(0.6627)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Age} \times ♀^2$	0.2882	0.9260	0.4983	0.4613	0.2361	0.9119	0.5428	0.4118
	(0.6449)	(0.8714)	(0.6939)	(0.7093)	(0.6472)	(0.8747)	(0.6948)	(0.7446)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♂$	0.0050	0.0097*	0.0063	1.7733	0.0049	0.0095*	0.0062	1.7286
	(0.0032)	(0.0043)	(0.0034)	(0.1499)	(0.0032)	(0.0043)	(0.0034)	(0.1587)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♂^2$	0.0001	0.0015*	0.0007*	7.8937	0.0001	0.0015*	0.0007*	7.7744
	(0.0003)	(0.0004)	(0.0003)	(0.0000)	(0.0003)	(0.0004)	(0.0003)	(0.0000)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♀$	−0.0038	−0.0054	−0.0095*	3.6408	−0.0042	−0.0056	−0.0094*	3.3297
	(0.0040)	(0.0054)	(0.0043)	(0.0122)	(0.0040)	(0.0054)	(0.0043)	(0.0187)
$\frac{\delta}{\theta'\upsilon_i}$: $\Delta\log \text{Days sick} \times ♀^2$	−0.0001	0.0006	0.0002	1.6138	−0.0001	0.0006	0.0002	1.6252
	(0.0003)	(0.0004)	(0.0003)	(0.1838)	(0.0003)	(0.0004)	(0.0003)	(0.1812)
Pregnant	−0.1690*	−0.2358*	−0.1841*	1.7446	−0.1680*	−0.2425*	−0.1821*	1.7901
	(0.0836)	(0.1130)	(0.0899)	(0.1555)	(0.0839)	(0.1134)	(0.0900)	(0.1467)
Nursing	−0.0100	−0.0130	−0.0092	0.4145	−0.0097	−0.0128	−0.0096	0.3740
	(0.0102)	(0.0138)	(0.0110)	(0.7426)	(0.0102)	(0.0138)	(0.0110)	(0.7718)
Second quarter	0.0769*	0.1220*	0.1018*	6.8836	0.0664*	0.1113*	0.0853*	4.5080
	(0.0214)	(0.0287)	(0.0228)	(0.0001)	(0.0233)	(0.0311)	(0.0247)	(0.0036)
Third quarter	0.0152	0.0887*	0.1046*	13.0204	0.0299	0.0971*	0.0986*	6.7058
	(0.0216)	(0.0292)	(0.0232)	(0.0000)	(0.0242)	(0.0328)	(0.0260)	(0.0002)
Fourth quarter	0.0867*	0.0017	−0.0175	14.8387	0.0763*	0.0014	−0.0012	4.8511
	(0.0218)	(0.0287)	(0.0230)	(0.0000)	(0.0290)	(0.0388)	(0.0309)	(0.0022)
y^p_{1t+1}	—	—	—	—	0.1465	0.0208	−0.2634	2.6952
	—	—	—	—	(0.2762)	(0.3711)	(0.2949)	(0.0443)
y^u_{1t+1}	—	—	—	—	−0.0075	−0.0074	0.0366	5.2212
	—	—	—	—	(0.0260)	(0.0352)	(0.0279)	(0.0013)
y^p_{it+1}	—	—	—	—	−0.7564*	−0.5663	−0.1424	7.2095
	—	—	—	—	(0.2659)	(0.3565)	(0.2831)	(0.0001)
y^u_{it+1}	—	—	—	—	0.0402	−0.0641	−0.0344	3.9802
	—	—	—	—	(0.0297)	(0.0402)	(0.0319)	(0.0076)

TABLE 7. Expenditure & nutritional intakes within the household. Dependent variables are changes in the logarithm of expenditures, kilocalories, and grams of protein, respectively. Point estimates may be interpreted as changes in person i's share of household food expenditures/calories/protein relative to the share of the female household head. Figures in parentheses are standard errors.