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

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

1. Introduction

In recent years, a variety of authors have sought to test the hypothesis that intra-household allocations are efficient. Often these have been construed as tests of the “collective household” model. Special cases of this model are associated with Samuelson (1956) and Becker (1974);

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

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

Consider referring to discussion of collective allocations in dynamic models in conclusion of ?.

Add there on how importance of individual characteristics and nutritional investment makes this exercise different from, e.g. Townsend (1994).

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

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

Second, in Section 3 we formulate a sequence of simple models, each corresponding to a dynamic program which characterizes the problem facing the household head in different environments. The first model is a simple ‘naive collective’ program, in which utility depends on consumption, but productivity does not. The head allocates consumption goods, makes investment decisions, and assigns activities to other household members. From this model we derive simple restrictions on household members’ intertemporal marginal rates of substitution. Working with a parametric representation of individuals’ utility functions, we exploit these restrictions to estimate a vector of preference parameters, which allows us to characterize changes in intra-household sharing rules as a function of observable individual characteristics such as age and sex.
Our second model generalizes the first, in that we allow for the possibility that food consumption may influence future productivity. In particular, while food consumption produces both direct utility (which depends on the quantity and quality of different kinds of foodstuffs), and also represents a sort of human capital investment which influences labor productivity (but this investment depends only on the quantity and nutritional content of foodstuffs, and \textit{not} food quality). This leads us to consider a model of nutritional investments, which reproduces some of the features of models formulated by, e.g., Pitt et al. (1990); Pitt and Rosenzweig (1985). In this model there is no private information and hence no need to provide incentives, but the head takes into account the effects that consumption has on both utility and productivity. This model also implies a set of restrictions on household members’ intertemporal marginal rates of substitution which distinguish it from the ‘naïve collective’ model. A key testable prediction of this model which distinguishes it from the naïve collective model is that if there’s an anticipated increase in the marginal product of labor for household member $i$, then nutritional investment in this member will increase at the same time that the quality of food consumed by $i$ decreases.

Finally, our third model extends the model with nutritional investment so that the off-farm labor effort of other household members isn’t necessarily observed by the household head.\footnote{\textquotedblright Off-farm labor” in this context means agricultural work on somebody else’s farm. Using the same dataset, Foster and Rosenzweig (1994) find evidence which suggests that the managers of such workers can’t observe labor effort, so that presumably the geographical remote household head can’t observe this effort either.} Accordingly, the intra-household sharing rule must be incentive compatible. The key difference between this model and the naïve collective model or the nutritional investment model is that household members must be provided with appropriate incentives to induce them to take the actions recommended by the household head. We show that in this model of efficient intra-household incentives food quality should respond to unpredicted individual earnings shocks. Section 5 concludes.

2. The Data

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

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 inequalitarian allocation, these differences provide no evidence to suggest that household allocations are inefficient.

3. SOME SIMPLE MODELS

Consider a household having $n$ members, indexed by $i = 1, 2, \ldots, n$, where an index of 1 is understood to refer to the household head. Time is indexed by $t = 0, 1, 2, \ldots$. During each period, member $i$ consumes a quantity of nutrients $c_{it}$. These nutrients have a corresponding quality $\varphi_{it}$, assumed to be bounded away from zero by $\varphi > 0$. At the same time, $i$ supplies some labor $a_{it}$.

Household member $i$ derives direct utility from both the quantity and quality of his consumption and disutility from his labor. Further, at time $t$ person $i$ possesses a set of characteristics (e.g., sex, health, age) which we denote by the $L$-vector $b_{it}$. These characteristics may have an influence on the utility he derives from both consumption and activities. Thus, we write his momentary utility at $t$ as some $U(\varphi_{it}, c_{it}, b_{it}) + Z_i(a_{it}, b_{it})$, where the function $U$ is assumed to be increasing, concave, and continuously differentiable in both the quantity and quality of nutrients, and where $Z_i$ is the disutility of labor $a_{it}$ for
3.1. **Stochastic Structure.** Households face two basic sources of uncertainty. First, in each period \( t \) an index of some public shock \( \theta_t \in \Theta = \{1, 2, \ldots, S\} \) is realized; among other things, the realization of \( \theta_t \) determines the prices faced by the household. Note that while publicly observed, this shock need not be common, including e.g., information on expected wages for different individuals. The probability of some particular \( \theta' \) occurring at time \( t \) may depend on the previous period’s realization \( \theta_{t-1} \) via a collection of Markovian transition probabilities \( \Pr(\theta_t|\theta_{t-1}) \), while the cumulative probability that the realization of \( \theta_t \) will be less than or equal to some value \( \theta' \) is written \( G(\theta'|\theta) = \sum_{r=1}^{\theta'} \Pr(r|\theta) \).

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

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

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

The implicit price of nutrients may depend on quality and the public shock. When the public shock is \( \theta' \), we write the price of a unit of nutrients having quality \( \varphi \) as \( p(\varphi, \theta') \).

**Assumption 1.** Let \( \Phi = [\varphi, \bar{\varphi}] \subset \mathbb{R} \). We make the following assumptions regarding the manner in which prices vary with quality:

1. \( p : \Phi \times \Theta \) is a continuously differentiable function of quality; we denote this derivative by \( p'(\varphi, \theta') \).
2. \( p \) is a strictly increasing function of quality.
3. \( p(\varphi, \theta') > 0 \) for all \( \theta' \in \Theta \).
4. The quality elasticity \( \eta(\varphi, \theta') \equiv p'(\varphi, \theta')/p(\varphi, \theta') \) is either strictly increasing in \( \varphi \) or is strictly decreasing in \( \varphi \).
5. For any \( \theta' \in \Theta \) there exists some \( \hat{\varphi} \in \Phi \) such that \( \eta(\hat{\varphi}, \theta') = 1 \).

The first three parts of this assumption are commonsensical: The prices of even low quality nutrients must always be positive, and higher quality nutrients must cost more. The last two parts are more restrictive, but turn out to be important if wishes to avoid corner solutions to the problem of choosing nutrient quality. A simple example price function which satisfies Assumption 1 is \( p(\varphi, \theta') = g(\theta')(\varphi + \varphi)\rho \), with both \( g(\theta') \) and \( \rho \) positive.

### 3.2. The Household Head’s Problem.

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

The head chooses the allocation of consumption only after observing the realization of \( \omega \), so that consumptions are assigned after individual outputs are determined and the public shock \( \theta' \) is observed. Allocating

\(^2\)There is a small literature devoted to the subject of division of responsibilities between adult males and females in Philippine households (e.g., Illo, 1995; Eder, 2006). Though unfortunately we can’t offer independent evidence from our dataset, this list of tasks seems to be consistent with the kinds of responsibilities typically undertaken by adult females, rather than males. Accordingly, we assume below that the senior female in the household is the household head unless noted otherwise.
consumption involves choosing both a vector of nutrients $c_i(\omega)$ to award to person $i$ in state $\omega$ as well as corresponding qualities $\varphi_i(\omega)$.

If in period $t$ the public shock was $\theta_t$, then for any time $t + 1$ realization of $\omega$ the head must satisfy the budget constraint

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

At the same time that the head allocates contemporaneous consumption, she also makes promises to other household members about their future levels of (discounted, expected) utility. Past promises must also be honored. Thus, if the head promised future utility $w_{it}$ to person $i$ at date $t - 1$, then honoring that promise requires that

$$\int [U(\varphi_{it}(\omega_t), c_{it}(\omega_t), b_{it}) + Z_i(a_{it}, b_{it}) + \beta w_{it+1}(\omega_t)] dH(\omega_t|a_t, \theta_t) = w_{it}.$$

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

**Program 1.**

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

subject to the household budget constraint

$$\sum_{i=1}^{n} p(\varphi_i(\omega), \theta')^T c_i(\omega) \leq \sum_{i=1}^{n} y_i - \sum_{i=1}^{n} z_i'$$

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

$$\int [U(\varphi_i(\omega), c_i(\omega), b_i) + Z_i(a_i, b_i) + \beta w_i'(\omega)] dH(\omega|a, z, \theta) = w_i,$$
for all \( i = 1, \ldots, n \); and subject finally to the requirement \( \varphi_i(\omega) \in \Phi \) for all \( i = 1, \ldots, n \) and all states \( \omega \in \Omega \).

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

**Lemma 1.** Let \( \alpha_{it} = \frac{\partial V}{\partial w_i}(w_t, z_t, b_t, \theta_t) \) in Program 1. If \( U(\varphi, c, b) \) is a concave function of \( (\varphi, c) \) for all \( b \), then \( \alpha_{it} = \alpha_{it+1} \) for all dates \( t \).

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

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

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

**Assumption 2.** We place the following restrictions on the form of the utility function for person \( i \):

(1) \( U(\varphi, c, b) = h(b)u_i(\varphi c) \);
(2) \( u_i : \mathbb{R} \to \mathbb{R} \) is strictly increasing, strictly concave, and continuously differentiable; and
(3) \( \lim_{x \to 0} u_i'(x) = \infty \).

The first part of this assumption implies that the utility function satisfies a form of separability between characteristics \( b \) and the quality and quantity of consumption; also, that the effect that characteristics have on the marginal utility of consumption take as common form across different people. The first part of Assumption 2 also implies that the utility of quantity and quality of nutrients depends on the product
of these two dimensions of the consumption bundle.\footnote{Assuming that utility depends on the product of quantity and quality is natural but also restrictive. It’s possible to relax this assumption considerably, by assuming, for example, that utility depends on an idiosyncratic Cobb-Douglas function of quantity and quality. The addition of this additional idiosyncratic element of individual preferences requires only modest changes to our results, which are available from the authors on request.} The second part of the assumption is entirely standard, while the third is one of the ‘Inada’ conditions which allows us to avoid having to worry about the possibility that the household head might assign zero consumption to any household member.

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

**Proposition 1.** If preferences satisfy Assumption 2 then the consumption allocations which solve Program 1 will satisfy

\[
\Delta \log \frac{u'_1(\varphi_1 c_1 t)}{u'_i(\varphi_i c_{i t})} = \Delta \log \frac{h(b_{i t})}{h(b_{1 t})} - \Delta \log \frac{p'_{i}(\varphi_{i t}, \theta_{t+1})}{p'_{1}(\varphi_{1 t}, \theta_{t+1})}
\]

for all \(i = 1, \ldots, n\), and all dates \(t\).

**Proof.** For any \(i = 2, \ldots, n\), let \(\alpha_i\) denote the Lagrange multiplier associated with the head of household’s corresponding promise-keeping constraint (5). We adopt the convention that \(\alpha_1 \equiv 1\).

Then the first order conditions from the head’s problem for \(\varphi_i\) can be rearranged to yield the following expression for person \(i\)’s consumption quantity in state \(\omega\):

\[
c_i(\omega) = \frac{\alpha_i}{\mu(\omega)} \frac{\partial U(\varphi_i(\omega), c_i(\omega), b_i)}{\partial \varphi} \frac{1}{p'(\varphi_i(\omega), \theta')} \]

where \(\mu(\omega)\) is the Lagrange multiplier of the collective household budget constraint when the public shock is \(\omega\), and where \(p'(\cdot, \theta')\) is the partial derivative of the price function with respect to quality \(\varphi\).

Dividing the expression given by (7) for the consumption quantity of person \(i > 1\) by the corresponding expression for \(i = 1\) yields

\[
\frac{c_i(\omega)}{c_1(\omega)} = \alpha_i \frac{\partial U(\varphi_1(\omega), c_1(\omega), b_1)}{\partial \varphi} \frac{p'(\varphi_1(\omega), \theta')}{p'(\varphi_i(\omega), \theta')}.
\]

Fix a particular period \(t\); Lemma 1 implies that \(\alpha_i\) is invariant over time. Then taking logarithms and differences across adjacent time
periods gives us

(8) \[ \Delta \log \frac{c_{it}}{c_{1t}} = \Delta \log \frac{\partial U(\varphi_{it}, c_{it}, b_{it})/\partial \varphi}{\partial U(\varphi_{1t}, c_{1t}, b_{1t})/\partial \varphi} + \Delta \log \frac{p'(\varphi_{it}, \theta_{t+1})}{p'(\varphi_{1t}, \theta_{t+1})} \]

Using Assumption 2, the first term on the right-hand side of this expression is equal to

\[ \Delta \log \frac{h(b_{it})}{h(b_{1t})} + \Delta \log \frac{c_{it}}{c_{1t}} + \Delta \log \frac{u'_i(\varphi_{it}c_{it})}{u'_1(\varphi_{1t}c_{1t})} \]

Substituting this into (8) yields the result.

When additional nutrients influence productivity, one can think of consumption as a sort of nutritional investment. The returns to this investment depend both on the marginal product of characteristics \(b\) and on the marginal impact that nutrition has on these characteristics. The marginal return to a nutritional investment in person \(i\) will generally depend on the utilities promised to all the members of the household \(w\), other investments \(z\), current characteristics \(b\), the shock \(\theta\), \(i\)'s consumption \(c_i\), and the household head’s current marginal utility of income, which we write as \(\mu\). Then the marginal return to additional nutritional investment in person \(i\) can be written

\[ R_i(c_i, w, z, b, \theta) = \frac{1}{\mu} \sum_{t=1}^{L} \frac{\partial V}{\partial b_i^t}(w, z, M(b, c, \theta), \theta) \frac{\partial M^t}{\partial c_i^t}(b, c, \theta). \]

Now consider the case in which there’s no return nutritional investment (food consumption doesn’t influence future characteristics). We express this case using the following

**Assumption 3.** The law of motion for characteristics \(M(b, c, \theta') = M(b, c, \theta)\) for all \((b, \theta')\) and all \(c, \theta' \in \mathbb{R}\).

Note that when Assumption 3 is satisfied, the returns to nutritional investment will be zero.

**Proposition 2.** If the price function satisfies Assumption 1, preferences satisfy Assumption 2 and Assumption 3 is satisfied, then the allocated quality of nutrients which solves Program 1 will not vary across individuals in the household, and the allocated quantities of nutrients will satisfy

(9) \[ \Delta \log c_{it} = \gamma_i \Delta \log c_{1t} + \frac{1}{\gamma_i} \Delta \log \frac{h(b_{it})}{h(b_{1t})} \]

for all \(i = 1, \ldots, n\), and all dates \(t\).
Proof. We begin by showing that \( \varphi_i = \varphi_1 \). The first order condition of Program 1 with respect to \( c_i(\omega) \) is

\[
\alpha_i \frac{\partial U}{\partial c}(\varphi_i(\omega), c_i(\omega), b_i) - \mu(\omega)p(\varphi_i(\omega), \theta') + \beta \mu(\omega)R_i(c_i(\omega), w(\omega), z', b, \theta') = 0.
\]

However, Assumption 3 implies that the term involving \( R_i \) is equal to zero. Using this fact along with Assumption 2 and re-arranging yields

\[
(10) \quad \alpha_i h(b_i) = \frac{\varphi_i(\omega)}{u_i'(\varphi_i(\omega)c_i(\omega))} = \mu(\omega)p(\varphi_i(\omega), \theta').
\]

The first order condition with respect to \( \varphi_i(\omega) \) is

\[
\alpha_i \frac{\partial U}{\partial \varphi}(\varphi_i(\omega), c_i(\omega), b_i) - \mu(\omega)p'(\varphi_i(\omega), \theta')c_i(\omega) = 0,
\]

which, so long as \( c_i(\omega) > 0 \), can be similarly re-arranged to yield

\[
(11) \quad \alpha_i h(b_i) = \frac{1}{u_i'(\varphi_i(\omega)c_i(\omega))} = \mu(\omega)p'(\varphi_i(\omega), \theta').
\]

Assumption 1 guarantees that the price \( p(\varphi, \theta') \) and its partial derivative with respect to \( \varphi \) will always be positive. Then dividing (10) by (11) and rearranging yields the result that

\[
\frac{p'(\varphi_i(\omega), \theta')}{p(\varphi_i(\omega), \theta')} \varphi_i(\omega) = 1.
\]

The last two parts of Assumption 1 guarantee that this equation has a unique solution. Then since the price function is common to all household members, the solution must be the same for all household members.

Next, we prove that (9) characterizes the allocation of quantities of nutrients. But since qualities are identical within the household, the ratio \( p'(\varphi_i, \theta')/p'(\varphi_1, \theta') = 1 \). Using this fact along with (6) from Proposition 1 yields (9). \( \square \)

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

Program 2.

\[
(12) \quad V(w, z, b, \theta) = \max_{\{a_i, z_i', \{\varphi_i(\omega), c_i(\omega), w_i'(\omega)\}_{\omega \in \Omega} \}_{i=1}^n} \int [U(\varphi_1(\omega), c_1(\omega), b_1) dH(\omega|a, z, \theta)]
\]

\[
+ Z_1(a_1, b_1) + \beta V(w'(\omega), z', M(b, c(\omega), \theta'))] dH(\omega|a, z, \theta)
\]
subject to the household budget constraint \((4)\) for all \(\omega = (y, \theta') \in \Omega\); and subject also to the set of promise-keeping constraints \((5)\). In addition, the household head must choose allocations and labor assignments which satisfy a set of incentive compatibility constraints

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

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

Program 2 is identical to Program 1 save for the addition of the incentive compatibility constraint \((13)\), which requires that person \(i\) will have no incentive to deviate from the action \(a_i\) recommended by the head. Unfortunately, it’s difficult to characterize the effects of this kind of hidden action when the requirement of incentive compatibility is expressed in the form of \((13)\). Accordingly, we also provide an alternative ‘relaxed’ program, which will have the same solutions so long as the so-called ‘first order approach’ is valid (Árpád Ábrahám and Pavoni, 2008).

Program 3.

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

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

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

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

Assumption 4. Any solution to the “relaxed” Program 3 is also a solution to Program 2.
Lemma 2. Let \( \alpha_{it} = \frac{\partial V}{\partial w_i}(w_t, z_t, b_t, \theta_t) \) in Program 3. If Assumption 4 is satisfied, then \( \alpha_{it} = \alpha_{it-1} + \nu_i \frac{f'_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}{f_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})} \) for all dates \( t \).

Proof. The envelope condition with respect to \( w_i \) in Program 1 implies that \( \frac{\partial V}{\partial w_i}(w_t, z_t, b_t, \theta_t) \equiv \alpha_{it} \) is equal to the Lagrange multiplier on the promise-keeping constraint (5). This fact along with the first order condition for the head’s problem with respect to \( w_i(\omega_{t+1}) \) then imply that \( \alpha_{it+1} = \alpha_{it} + \nu_i \frac{f'_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}{f_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})} \). By Assumption 4, these first order conditions to characterize the solution to the head’s problem in Program 2.

Proposition 3. If preferences satisfy Assumption 2 and Assumption 4 then the consumption allocation for person \( i \) at time \( t \) solving Program 2 will satisfy

\[
\Delta \log \frac{u'_i(\varphi_{it}c_{it})}{u'_i(\psi_{it}c_{it})} = \Delta \log \frac{h(b_{it})}{h(b_{1t})} - \Delta \log \frac{p'(\varphi_{it}, \theta_{t+1})}{p'(\psi_{it}, \theta_{t+1})} + \log \left[ 1 + \frac{\nu_i f'_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}{\alpha_{it} f_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})} \right]
\]

for some non-negative scalar \( \nu_{it} \).

Proof. Let \( \alpha_{it} \) denote the Lagrange multiplier associated with the promise-keeping constraint (5) for person \( i \) in period \( t \). Then the first order conditions from the head’s problem for \( \varphi_i \) and \( \psi_1 \) imply that

\[
\frac{\partial U(\varphi_{it}, c_{it}, b_{it})}{\partial \varphi} \left[ \alpha_{it} + \nu_{it} \frac{f'_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}{f_i(y_{it}|a_{it}, z_{it}, \theta_{t+1})} \right] = \frac{p'(\varphi_{it}, \theta_{t+1}) c_{it}}{p'(\psi_{it}, \theta_{t+1}) c_{it}},
\]

where \( \nu_{it} \) is the Lagrange multiplier associated with the constraint (8). Lemma 2 implies that the expression in brackets on the left-hand side of (18) is equal to \( \alpha_{it+1} \); using this fact, we can write

\[
\alpha_{it+1} = \frac{\partial U(\varphi_{it}, c_{it}, b_{it})}{\partial \varphi} \frac{p'(\varphi_{it}, \theta_{t+1}) c_{it}}{p'(\psi_{it}, \theta_{t+1}) c_{it}}.
\]

Using Assumption 2, this becomes

\[
\alpha_{it+1} = \frac{u'_i(\varphi_{it}c_{it})}{u'_i(\psi_{it}c_{it})} \frac{p'(\varphi_{it}, \theta_{t+1}) h(b_{it})}{p'(\varphi_{it}, \theta_{t+1}) h(b_{it})}.
\]
Combining this with (??) it follows that
\[
\frac{u'_i(\varphi_{it}c_{it})}{u'_i(\varphi_{it}c_{it})} \frac{p'(\varphi_{it}, \theta_{t+1})}{p'(\varphi_{it}, \theta_{t+1})} \frac{h(b_{it})}{h(b_{it})} = \frac{u'_i(\varphi_{it-1}c_{it-1})}{u'_i(\varphi_{it-1}c_{it-1})} \frac{p'(\varphi_{it-1}, \theta_t)}{p'(\varphi_{it-1}, \theta_t)} \frac{h(b_{it-1})}{h(b_{it-1})} + \nu_{it} \frac{f^i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}{f^i(y_{it}|a_{it}, z_{it}, \theta_{t+1})}.
\]

Dividing this expression on both sides by \(\alpha_{it}\), taking logarithms, and rearranging yields the result, with \(\hat{\nu}_{it} = \nu_{it}/\alpha_{it-1}\).

We also have a corresponding characterization governing the assignment of quality, given by the following proposition.

**Proposition 4.** If prices satisfy Assumption 1, preferences satisfy Assumption 2, and Assumption 4 holds then any interior quality assignment which solves Program 2 will satisfy

\[
\varphi_i(\omega) = \frac{p(\varphi_i(\omega), \theta')}{p'(\varphi_i(\omega), \theta')} - \frac{\beta}{p'(\varphi_i(\omega), \theta')} R_i(c_i(\omega), w(\omega), z', b, \theta').
\]

**Proof.** The first order condition of Program 2 with respect to \(c_i(\omega)\) is

\[
\frac{\partial U}{\partial c} (\varphi_i(\omega), c_i(\omega), b_i) \left[ \alpha_i + \nu_i \frac{f^i(y_i|a_i, z_i, \theta')}{f^i(y_i|a_i, z_i, \theta')} \right] - \mu(\omega)p(\varphi_i(\omega), \theta') + \beta \mu(\omega)R_i(c_i(\omega), w(\omega), z', b, \theta') = 0.
\]

Using Assumption 2 and re-arranging, this yields

\[
\frac{\varphi_i(\omega)}{[\varphi_i(\omega)c_i(\omega)]^{\gamma_i}} \left[ \alpha_i + \nu_i \frac{f^i(y_i|a_i, z_i, \theta')}{f^i(y_i|a_i, z_i, \theta')} \right] = \mu(\omega)p(\varphi_i(\omega), \theta') - \beta \mu(\omega)R_i(c_i(\omega), w(\omega), z', b, \theta').
\]

The first order condition with respect to \(\varphi_i(\omega)\) is

\[
\frac{\partial U}{\partial \varphi} (\varphi_i(\omega), c_i(\omega), b_i) \left[ \alpha_i + \nu_i \frac{f^i(y_i|a_i, z_i, \theta')}{f^i(y_i|a_i, z_i, \theta')} \right] - \mu(\omega)p'(\varphi_i(\omega), \theta') = 0,
\]

which, so long as \(c_i(\omega) > 0\), can be similarly re-arranged to yield

\[
\frac{1}{[\varphi_i(\omega)c_i(\omega)]^{\gamma_i}} \left[ \alpha_i + \nu_i \frac{f^i(y_i|a_i, z_i, \theta')}{f^i(y_i|a_i, z_i, \theta')} \right] = \mu(\omega)p'(\varphi_i(\omega), \theta').
\]

Dividing (20) by (21) then yields the result. \(\square\)

Proposition 4 allows us to characterize the assignment of quality within the household when there is both nutritional investment and also hidden actions. What if there are hidden actions but no nutritional investment?
### Corollary 1. If the assumptions of Proposition 4 are satisfied and in addition Assumption 3 holds, then assigned quality will not vary across members of the household, and the provision of incentives will be achieved only via changes in the quantity of nutrients, not their quality.

### 4. Empirical Tests

#### 4.1. Distinguishing among regimes.

The model we’ve described above gives rise to four different possible regimes, depending on whether or not consumption influences subsequent productivity (Assumption 3) and on whether or not household members take actions which are hidden from the household head. Table 2 summarizes the connections between model characteristics and regimes, while Table 3 describes the pattern of correlations between both predicted and unpredicted changes in earnings with both the quality and quantity of nutrients. It’s ultimately differences in the pattern of these correlations predicted which allows us to advance a claim regarding the regime which actually prevails in the real-world environment which generates the data described in Section 2.

In the naive collective regime current consumption contributes only to utility, and doesn’t influence productivity or other characteristics. This regime is analogous to that envisioned in most research on inter-household risk-sharing, such as Townsend (1994). Idiosyncratic
earnings shocks will be efficiently shared in the naive collective regime, with the consequence that these shocks will have no influence on person $i$’s consumption relative to the consumption of the household head (per Proposition 1). Further, since in this regime consumption has no influence on productivity or other characteristics of household members, then the assigned quality of nutrients will be the same across all members of the household.

In the incentives regime current consumption contributes only to utility, and doesn’t influence productivity or individual characteristics. However, because actions are hidden, the household head may award additional consumption to members with unexpectedly high earnings as a way of preventing shirking or reducing consumption for household members with earnings which are less than expected. Thus, idiosyncratic earnings shocks may be correlated with changes to quantities of individual consumption (relative to the household head), via Proposition 3. Perhaps surprisingly, the quality of nutrients will be constant across household members, as in the naive collective model—it’s optimal to provide incentives only by varying the quantity of nutrients, not quality (cf. Proposition 4).

The third regime, nutritional investment, is one in which the allocation of nutrients 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 to changes in the expected marginal productivity of actions for a particular household member. 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. Thus, in the nutritional investment regime our model predicts that the quantity of nutrients consumed will be positively correlated with earnings shocks. Perhaps more surprisingly, the model predicts that in this regime the quality of nutrients will be negatively correlated with those shocks, per Proposition 2. The basic idea is that since the household member is being given additional quantities of food (which increases not only productivity but also utility), the household head can reduce the quality of food while still making good on *ex ante* utility promises.

The fourth regime combines the attributes of the nutritional investment regime and the incentives regime, and so we title it incentives and investment. In this regime consumption is allocated *both* as an investment and to provide incentives for household members to exert
themselves. In this regime our model predicts that unpredictable earnings shocks will be positively correlated with quantities of nutrients. Further, when one considers the sign of correlation between predictable earnings shocks and quality, the prediction of the model in the investment and incentives regime is unambiguous—predictable earnings shocks should be \textit{negatively} correlated with quality.

Though in the investment and incentive regime predictable earnings shocks will be negatively correlated with consumption quality, the direction of the effect of \textit{unpredictable} earnings shocks on quality is ambiguous. Increased quantities of nutrition assigned to a worker for investment purposes will lead the household to reduce the quality assigned, but the efficient provision of incentives in this regime calls for an increase in quality, so the ultimate sign of the correlation between unexpected earnings shocks and quality depends on which of the investment or incentives effects dominate.

4.2. \textbf{Testing for Nutritional Investment}. Proposition 3 and Proposition 4 provide us with the basis for the estimating equations which permit us to distinguish among regimes and to estimate the parameters of the intra-household demand system when there is either nutritional investment or the provision of incentives in the face of hidden actions.

We first consider how to test the hypothesis that there is no nutritional investment, by using the result of of Proposition 4. Assumption 3 holds by assumption, so that (19) implies that

\begin{equation}
\varphi_{it} = \varphi_{1t},
\end{equation}

where the subscripts \( t \) indicate that the relationship holds given the state \( \omega \) realized at \( t \). (22) takes advantage of our result Corollary ?? that in the absence of any motive for making nutritional investments incentives are most efficiently provided by varying the quantity of consumption rather than its quality.

In the absence of nutritional investments, quality-adjusted prices \( p(\varphi_{it}, \theta_{it}) \) will not vary within the household. However, the quality-adjusted prices \( p_{it} \) which we actually observe in the data (e.g., expenditures per Calorie) are measured with a multiplicative error having an unknown mean. We assume that the distribution of the measurement error is stationary and independent over time; also, that its logarithm is mean independent of other observables. Then taking logarithms and differences of (22) gives the system of estimating equations

\begin{equation}
\Delta \log p_{it} = \beta_0 + \beta_1 \Delta \log p_{1t} + e_{it},
\end{equation}
where the null hypothesis of no nutritional investment implies the testable restrictions that $\beta_1 = 1$ and that $E(e_{it}|\Delta \log \zeta_{jt}, \Delta \log y_{jt}, \theta_t) = 0$ for all $j = 1, \ldots, n$.

Here, for time-varying individual characteristics $\log \zeta_{it}$, we use a set of time effects, interactions between sex and the logarithm of age in years 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 each of these measures we compute the difference between the value of the measure for person $i$ and the value of the same measure for the household head. For fixed individual characteristics, we’ve simply used the person’s sex. We report results using both the changes in the unit cost per Calorie and the unit cost per gram of protein. Results are reported in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>Calorie cost</th>
<th>Protein cost</th>
<th>$F$ ($p$-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head’s quality $\times$ $i$’s sex: Male</td>
<td>3.8164*</td>
<td>1.8719*</td>
<td>1615.2035</td>
</tr>
<tr>
<td></td>
<td>(0.1087)</td>
<td>(0.0365)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>Head’s quality $\times$ $i$’s sex: Female</td>
<td>1.5882*</td>
<td>1.0857*</td>
<td>470.3805</td>
</tr>
<tr>
<td></td>
<td>(0.0985)</td>
<td>(0.0381)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>Age male</td>
<td>0.0036*</td>
<td>-0.0183</td>
<td>10.1705</td>
</tr>
<tr>
<td></td>
<td>(0.0017)</td>
<td>(0.0257)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>Age female</td>
<td>0.0000</td>
<td>0.0140</td>
<td>0.2853</td>
</tr>
<tr>
<td></td>
<td>(0.0020)</td>
<td>(0.0297)</td>
<td>(0.7518)</td>
</tr>
<tr>
<td>Days sick, male (minus head)</td>
<td>0.0001*</td>
<td>0.0009</td>
<td>5.4003</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0006)</td>
<td>(0.0045)</td>
</tr>
<tr>
<td>Days sick, female (minus head)</td>
<td>0.0000</td>
<td>0.0010</td>
<td>1.1505</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0008)</td>
<td>(0.3165)</td>
</tr>
<tr>
<td>Pregnant (minus head pregnant)</td>
<td>0.0003</td>
<td>-0.0016</td>
<td>0.1688</td>
</tr>
<tr>
<td></td>
<td>(0.0011)</td>
<td>(0.0159)</td>
<td>(0.8447)</td>
</tr>
<tr>
<td>Minutes Nursing (minus head’s minutes nursing)</td>
<td>-0.0000</td>
<td>-0.0007</td>
<td>0.1451</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0019)</td>
<td>(0.8649)</td>
</tr>
<tr>
<td>Second quarter</td>
<td>0.0004</td>
<td>0.0048</td>
<td>1.1122</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0039)</td>
<td>(0.3289)</td>
</tr>
<tr>
<td>Third quarter</td>
<td>-0.0007*</td>
<td>-0.0112*</td>
<td>4.0745</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0040)</td>
<td>(0.0170)</td>
</tr>
<tr>
<td>Fourth quarter</td>
<td>0.0011*</td>
<td>0.0147*</td>
<td>8.0336</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0041)</td>
<td>(0.0003)</td>
</tr>
</tbody>
</table>

Table 4. Changes in the allocation of food quality.
Either of the regimes without nutritional investment implies that the coefficient associated with the quality of the head’s consumption should be one. In Table 4 we interact the (change in the logarithm of) the head’s consumption quality with the sex of person $i$, allowing us to test whether changes in the allocation of quality within the household depend on sex. Variables used to estimate (23) are all transformed in such a way that the estimated coefficients can be estimated as elasticities.

The first two rows of Table 4 provide a dramatic rejection of the hypothesis that nutritional investment doesn’t matter. For every one per cent increase in the cost per Calorie for the head, we estimate that males in the household will receive an increase of 3.8 per cent, while other females in the household will receive an increase of 1.5 per cent. Each of these estimated coefficients is highly significant, and significantly different from one. We infer that the assignment of food within households in our dataset depends to some extent on nutritional investments, and assert with a very high degree of confidence that neither the naive unitary regime nor the pure incentive regime describes the mechanism used to assign food quality in the Philippine setting which generated our data.

In the pure nutritional investment regime there there are no unobserved actions, and hence no need to provide incentives. In this case (19) implies that quality will vary negatively with the expected marginal benefit of nutritional investments. However, a rejection of the hypothesis that quality is perfectly correlated in the household is also consistent with the investment and incentives regime. To distinguish between these two regimes we need to consider the possibly distinct effects of

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

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

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

APPENDIX B. ESTIMATOR

In this appendix we devise an estimator with which to estimate the system of equations

\[ \Delta \log (x_{it}^k) = \Delta \log (x_{1it}^k) \frac{\theta_k^i v_{1i}}{\theta_k^i v_i} + (\Delta \zeta_{it} - \Delta \zeta_{1it}) \frac{\delta}{\theta_k^i v_i} + \nu_{it}^k \]

for \( k = 1, 2, 3 \) and with \( \nu_{it}^k = \frac{\epsilon_{it}^k}{\theta_k^i v_i} \).

\[
\text{cov} \left( \nu_{it}^k, \nu_{i't}^{k'} \right) = \text{cov} \left( \frac{\epsilon_{it}^k}{\theta_k^i v_i}, \frac{\epsilon_{i't}^{k'}}{\theta_k^{i'} v_{i'}} \right) = \frac{1}{\theta_k^i v_i \theta_k^{i'} v_{i'}} \text{cov} (\epsilon_{it}^k, \epsilon_{i't}^{k'})
\]

(1) One can assume that

\[
\text{cov} \left( \nu_{it}^k, \nu_{i't}^{k'} \right) = \sigma_{kk'} \text{ if } i = i' \\
= 0 \text{ if } i \neq i'
\]

and

\[
E \left( \nu_{it}^k | \Delta \log (x_{1it}^k), (\Delta \zeta_{it} - \Delta \zeta_{1it}) \right) = 0
\]
In this case, FGLS allows to estimated consistently all parameters, for all $k$ \( \frac{\partial' \nu_i}{\partial' \nu_{i'}} \). 

(2) One can still have 

\[
\text{cov} \left( v_{it}^k, v_{i't}^{k'} \right) = \sigma_{kk'} \text{ if } i = i' \\
= 0 \text{ if } i \neq i'
\]

but that 

\[
E \left( v_{it}^k \mid \Delta \log (x_{1t}^k), (\Delta \zeta_{it} - \Delta \zeta_{1t}) \right) \neq 0
\]

because of an endogeneity problem, that is that shocks $v_{it}^k$ are correlated with the head’s shock and thus with the head’s changes of log-consumption (or log-protein, or log-calories).

Then, taking advantage of the availability of household level data on consumption measures, coming from a different module an measurement method of the survey, we use these data as instrumental variables for household head’s changes in consumption or food intakes.

Denoting by $c_{it}^k$ the household level consumption of good $k$ by household of individual $i$ at period $t$, we assume that 

\[
E \left( v_{it}^k \mid c_{it}^k, (\Delta \zeta_{it} - \Delta \zeta_{1t}) \right) = 0
\]

Then we can estimate parameters, for all $k$ \( \frac{\partial' \nu_i}{\partial' \nu_{i'}} \), \( \frac{\delta}{\partial' \nu_{i'}} \) by 3SLS.

(3) We could also argue that the correlation of residuals of food equations across members of a same household should not be zero. Then, we can choose to specify the correlation structure such that for some vector $z$ of observable variables:

\[
\text{cov} \left( v_{it}^k, v_{i't}^{k'} \right) = \sigma_{kk'} \lambda_{kk'} \left( z_i - z_{i'} \right)
\]

where $\lambda_{kk'} (0) = 1$, $z$ can be a vector.

A special case constitutes the case where $\lambda_{kk'} (.) = \lambda (.), \forall k, k'$. 

\[
\text{cov} \left( v_{it}^k, v_{i't}^{k'} \right) = \sigma_k \sigma_{k'} \lambda \left( z_i - z_{i'} \right) \\
\lambda (0) = 1
\]

(4) Assuming that 

\[
\text{cov} \left( \epsilon_{it}^k, \epsilon_{i't}^{k'} \right) = \sigma_{kk'} \text{ if } i = i' \\
= 0 \text{ if } i \neq i'
\]
then

$$\text{cov} \left( v_{ik}^k, v_{i'k'}^k \right) = \text{cov} \left( \frac{\epsilon_{ikt}^k}{(\theta_{k}^i)^2}, \frac{\epsilon_{i't'}^k}{(\theta_{k'}^{i'})^2} \right) = \frac{\sigma_{kk'}}{(\theta_{k}^i) (\theta_{k'}^{i'})} \text{ if } i = i' \text{ and } = 0 \text{ if } i \neq i'$$

Notations:

$$\epsilon^k = \begin{bmatrix} \epsilon_{11}^k \\ \vdots \\ \epsilon_{NT}^k \end{bmatrix}, \quad X^{k'} = \begin{bmatrix} X_{11}^k \\ \vdots \\ X_{NT}^k \end{bmatrix} = \begin{bmatrix} (X_{11}^k(1), \ldots, X_{11}^k(p)) \\ \vdots \\ (X_{NT}^k(1), \ldots, X_{NT}^k(p)) \end{bmatrix} \quad (\text{dim: } NT \times p),$$

$$Z^k = \begin{bmatrix} Z_{11}^k \\ \vdots \\ Z_{NT}^k \end{bmatrix} = \begin{bmatrix} (Z_{11}^k(1), \ldots, Z_{11}^k(k)) \\ \vdots \\ (Z_{NT}^k(1), \ldots, Z_{NT}^k(k)) \end{bmatrix} \quad (\text{dim: } NT \times k), \quad Y^k = \begin{bmatrix} Y_{11}^k \\ \vdots \\ Y_{NT}^k \end{bmatrix} \quad (\text{dim: } 3NT \times 1)$$

$$\epsilon = \begin{bmatrix} \epsilon_1^1 \\ \epsilon_2^1 \\ \epsilon_3^1 \end{bmatrix} \quad (\text{dim: } 3NT \times 1), \quad X = \begin{bmatrix} X^1 & 0 & 0 \\ 0 & X^2 & 0 \\ 0 & 0 & X^3 \end{bmatrix} \quad (\text{dim: } 3p \times 3NT), \quad \beta = \begin{bmatrix} \beta_1^1 \\ \beta_2^1 \\ \beta_3^1 \end{bmatrix} \quad (\text{dim: } 3p \times 1)$$

$$Z = \begin{bmatrix} Z_1^1 \\ Z_2^1 \\ Z_3^1 \end{bmatrix} \quad (\text{dim: } 3NT \times k), \quad Y = \begin{bmatrix} Y_1^1 \\ Y_2^1 \\ Y_3^1 \end{bmatrix} \quad (\text{dim: } 3NT \times 1)$$
Then
\[ Y = X' \beta + \epsilon \]
\[ \dim : (3NT \times 1) = (3NT \times 3p) \times (3p \times 1) + (3NT \times 1) \]

Denoting
\[ P_Z = Z(Z'Z)^{-1}Z' \]
\[ \dim : (3NT \times 3NT) \]

we have
\[ \beta_{OLS} = (X'X)^{-1}X'Y \]
\[ \beta_{IV} = (X'P_ZX)^{-1}X'P_ZY \]
\[ \beta_{GLS} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y \]
\[ \beta_{IVGLS} = (X'P_Z\Omega^{-1}P_ZX)^{-1}X'P_Z\Omega^{-1}Y \]

\[ \text{var}(\beta_{OLS}) = (X'X)^{-1} \]
\[ \text{var}(\beta_{IV}) = (X'P_ZX)^{-1} \]
\[ \text{var}(\beta_{GLS}) = (X'\Omega^{-1}X)^{-1} \]
\[ \text{var}(\beta_{IVGLS}) = (P_ZX\Omega^{-1}X'P_Z)^{-1} \]

where \( \Omega = E(\epsilon \epsilon') \)
\[ \Omega = E(\epsilon \epsilon') = E \begin{pmatrix} \epsilon_1^1 \\ \epsilon_2^2 \\ \epsilon_3^3 \end{pmatrix} \begin{pmatrix} \epsilon_1^1 \\ \epsilon_2^2 \\ \epsilon_3^3 \end{pmatrix}' = \begin{pmatrix} E\epsilon_1^1 \epsilon_1^1 & E\epsilon_1^2 \epsilon_2^1 & E\epsilon_1^3 \epsilon_3^1 \\ E\epsilon_2^2 \epsilon_1^1 & E\epsilon_2^2 \epsilon_2^2 & E\epsilon_2^3 \epsilon_3^2 \\ E\epsilon_3^3 \epsilon_1^1 & E\epsilon_3^3 \epsilon_2^2 & E\epsilon_3^3 \epsilon_3^3 \end{pmatrix} \] (dim : 3NT \times 3NT)

Using the matrix notations:
- When
  \[ \text{cov}(\epsilon_{it}^k, \epsilon_{i't}^{k'}) = \sigma_{kk'} \text{ if } i = i' \]
  \[ = 0 \text{ if } i \neq i' \]

then
\[ \Omega = \Sigma_3 \otimes I_{NT} \]

with
\[ \Sigma_3 = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{pmatrix} \]

\[ \Omega^{-1} = \Sigma_3^{-1} \otimes I_{NT} \]

Thus
\[ \beta_{GLS} = (X' (\Sigma_3^{-1} \otimes I_{NT}) X)^{-1}X' (\Sigma_3^{-1} \otimes I_{NT}) Y \]
\[ \beta_{IVGLS} = (X'P_Z (\Sigma_3^{-1} \otimes I_{NT}) P_Z X)^{-1}X'P_Z (\Sigma_3^{-1} \otimes I_{NT}) Y \]
• When

\[ \text{cov}(e_{it}^k, e_{i't}^{k'}) = \sigma_{kk'}\lambda(z_{it} - z_{i't'}) \]

then

\[ \Omega = \Sigma_3 \otimes \Sigma(z) \]

with

\[ \Sigma(z) = I_{NT} + \lambda \left( (z * J_{1,NT}) - (z * J_{1,NT})' \right) \]

\[ \Omega^{-1} = \Sigma_3^{-1} \otimes \Sigma(z)^{-1} \]

• When

\[ \text{cov}(\frac{e_{it}^k}{\theta_k' u_i}, \frac{e_{i't}^{k'}}{\theta_{k'}' u_{i'}}) = \frac{\lambda(z_{it} - z_{i't'})}{(\theta_k' u_i) (\theta_{k'}' u_{i'})} \]

then

\[ \Omega = \Sigma_3 \otimes \Sigma(z) \]

with

\[ \Sigma(z) = (I_{NT} + \lambda \left[ (z * J_{1,NT}) - (z * J_{1,NT})' \right]) \cdot / (A) \]

where \( / \) is for the element by element division and

\[ A[it, i't'] = (\theta_k' u_i) (\theta_{k'}' u_{i'}) \]

\[ \Omega^{-1} = \Sigma_3^{-1} \otimes \Sigma(z)^{-1} \]

REFERENCES


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