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

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ABSTRACT. We construct a model of food demand which distinguishes between the nutrients supplied by a particular food bundle and the quality of that bundle, as measured by its cost. We show that when nutrition affects only utility then under rather general conditions it will be optimal for all members of the household to consume food bundles of identical quality. This is true even when household members have private information about their actions—in this case the *quantity* of food given may provide incentives, but quality remains common within the household.

When nutrition affects household resources our finding that quality is constant is overturned—in this case when the household invests more in the nutrition of one member it will simultaneously *reduce* the quality of her food bundle.

Using data on individual-level food consumption from a sample of farm households in the Philippines, we estimate and test a dynamic model of intra-household food allocation. We find that individual consumption shares respond to individual earnings shocks. At least part of this response is due to nutritional investments, but it appears that the allocation of food also plays a role in providing incentives within the household.

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1. Introduction

In recent years, a variety of authors have sought to test the hypothesis that intra-household allocations are efficient. Often these have been construed as tests of the "unitary" or "collective" household model. Special cases of this model are associated with Samuelson (1956) and Becker (1974); more recent formulations are associated with work by McElroy, Chiappori, and others (e.g. McElroy, 1990; Browning and Chiappori, 1998; Chiappori, 1992).

We use data on individual level food allocation and individual earnings to try and better understand the process which determines the allocation of food within households in the rural Philippines. In a companion paper (Dubois and Ligon, 2009) we find that an individual's share of household food expenditures responds to individual-level variation in earnings. This means that we can reject at least a naive version of the unitary model—in that model idiosyncratic shocks to earnings would be insured away, and individual level consumption shares would remain constant.

Consider referring to discussion of collective allocations in dynamic models in conclusion of Bourguignon et al. (2009).

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 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*.

In this paper we make an attempt to sort out two different hypotheses which could explain the response of consumption shares to earnings. One is what we'll call the hypothesis of *nutritional investment*; the household allocates more food to some individuals because the returns to this kind of nutritional investment are higher than for other individuals. If, for example, one family member has the opportunity to earn more by ploughing others' fields (a task which requires both strength and energy) then he may receive both more calories and protein than other family members engaged in less strenous and remunerative tasks. A second hypothesis is that food is used to provide *incentives* because there are hidden actions taken by family members. For example, when one goes to work in another's field his efforts may be unobserved by the household head. Under this hypothesis, a family member who brings home higher than usual earnings may be rewarded with more food.

Our approach to distinguishing between these two hypotheses involves developing a model in which food is characterized both by its *quantity* (measured in nutrients) and its *quality* (measured in terms of cost for a given nutrient bundle). People are assumed to derive utility from both the quality and quantity of the food they consume. One surprising result is that under what we regard as fairly general conditions food quality will vary across individuals in the household only when nutritional investment is important:

even when there are hidden actions and food provides incentives, these incentives will involve only varying the *quantity* and not the *quality* of food unless nutritional investments matter.

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 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 unitary program, in which there's full information, and both utility and productivity depend on food consumption. 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 for nutrient bundles, and also on the allocation of quality across people within the household. 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. This model of nutritional investment with a fully-informed household head reproduces some of the features of models formulated by, e.g., Pitt et al. (1990) or Pitt and Rosenzweig (1985). In this model there is no private information and hence no need to provide incentives, but the optimal allocation of food depends on the effect that consumption has on both utility and productivity.

We next extend the model with nutritional investment so that the off-farm labor effort of other household members isn't necessarily observed by the household head.[1] Accordingly, the intra-household sharing rule must be incentive compatible. The key difference between this model and the naive collective model or the nutritional investment model is that household members must be provided with appropriate incentives to induce them to take the actions recommended by the household head. We show that in this model of efficient intra-household incentives food quantity should respond to unpredicted individual earnings shocks whether or not there's also nutritional investment, but that food quality should respond only if nutritional investment is important.

[1]"Off-farm labor" in this context means agricultural work on land operated by some other household. Using the same dataset, **?** find evidence which suggests that the managers of such workers can't observe labor effort, so that presumably the geographically remote household head can't observe this effort either.

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 **?** 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.

2.1. Survey Design.

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 out-migration) occurred during the study—a total of 448 households from ten villages finally participated in the four surveys conducted at four month intervals beginning in July 1984. The total number of persons in the survey is 3294.

2.2. Food Expenditures and Nutrition.

The nutritional component of the survey involved interviewed respondents to elicit recall of individual food intake over the previous twenty-four hours. In addition, there were monthly interviews to measure household-level food expenditures, and every four month interviews to measure household level non-food expenditures. The measurement of food intake involved collecting data on quantity purchased (along with prices) at the household level, and the quantity consumed at the individual level. Information on both individual- and household-level food consumption was highly disaggregated. For individual level consumption, data was collected on over eighty different items or dishes. For each dish, there was a corresponding recipe mapping ingredients into quantities of the dish. One can then back out the quantities of all ingredients implied by the data collected on dishes. For almost all of these, there is a corresponding entry in a food conversion table which translates quantities of each ingredient into a basket of nutrients. Individual food expenditures are computed using information on prices from the household expenditure survey, multiplied times the quantities consumed by different inviduals. Appropriate

	Expend.	Rice	Corn	Staples	Meat	Veg.	Snacks	Calories	Protein
Sample	6.38	0.80	1.30	0.32	1.98	0.53	0.90	1972.15	58.94
Male	7.06	0.89	1.39	0.31	2.12	0.55	1.25	2100.17	62.56
Female	5.66	0.69	1.21	0.32	1.83	0.51	0.54	1837.44	55.13
≤ 5 years	3.80	0.40	0.73	0.23	1.41	0.24	0.39	1137.08	34.89
6–10 years	4.84	0.62	1.05	0.28	1.64	0.37	0.43	1618.38	48.50
11–15 years	6.88	0.87	1.51	0.37	2.24	0.62	0.63	2232.41	66.06
16–25 years	7.93	1.06	1.61	0.36	2.27	0.76	1.24	2412.47	71.97
26–50 years	8.88	1.01	1.61	0.36	2.49	0.69	2.07	2416.09	72.50
> 50 years	7.12	0.88	1.44	0.25	1.88	0.57	1.36	2136.46	61.65
≤ 5 years (Male)	3.72	0.42	0.73	0.23	1.41	0.22	0.29	1166.96	35.48
6–10 years (Male)	5.01	0.69	1.04	0.28	1.73	0.37	0.46	1653.66	49.33
11–15 years (Male)	7.11	0.92	1.67	0.38	2.28	0.58	0.72	2360.03	69.04
16–25 years (Male)	9.46	1.21	1.83	0.35	2.62	0.84	1.96	2688.41	80.57
26–50 years (Male)	10.41	1.18	1.77	0.35	2.69	0.74	3.01	2653.38	79.36
> 50 years (Male)	7.96	1.04	1.50	0.23	1.94	0.63	1.73	2300.73	66.91
≤ 5 years (Female)	3.90	0.37	0.72	0.22	1.41	0.27	0.50	1101.53	34.18
6–10 years (Female)	4.66	0.55	1.06	0.28	1.54	0.36	0.40	1582.22	47.65
11–15 years (Female)	6.66	0.82	1.36	0.36	2.20	0.66	0.55	2109.17	63.18
16–25 years (Female)	6.61	0.93	1.42	0.37	1.97	0.69	0.62	2176.37	64.62
26–50 years (Female)	6.86	0.78	1.41	0.37	2.23	0.63	0.84	2102.99	63.43
> 50 years (Female)	4.57	0.39	1.27	0.30	1.67	0.39	0.25	1639.46	45.76

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.

adjustments are made to account for food consumed out of own-production or in-kind transactions.

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 2. 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 2 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 2. 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.

	Expend.	Rice	Corn	Staples	Meat	Veg.	Snacks	Calories	Protein
Sample	6.38	0.80	1.30	0.32	1.98	0.53	0.90	1972.15	58.94
Male	7.06	0.89	1.39	0.31	2.12	0.55	1.25	2100.17	62.56
Female	5.66	0.69	1.21	0.32	1.83	0.51	0.54	1837.44	55.13
≤ 5 years	3.80	0.40	0.73	0.23	1.41	0.24	0.39	1137.08	34.89
6–10 years	4.84	0.62	1.05	0.28	1.64	0.37	0.43	1618.38	48.50
11–15 years	6.88	0.87	1.51	0.37	2.24	0.62	0.63	2232.41	66.06
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11–15 years (Female)	6.66	0.82	1.36	0.36	2.20	0.66	0.55	2109.17	63.18
16–25 years (Female)	6.61	0.93	1.42	0.37	1.97	0.69	0.62	2176.37	64.62
26–50 years (Female)	6.86	0.78	1.41	0.37	2.23	0.63	0.84	2102.99	63.43
> 50 years (Female)	4.57	0.39	1.27	0.30	1.67	0.39	0.25	1639.46	45.76

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2.3. **Weather.** Weather data coming from the weather station of Malay Balay which is at the center of the Bukidnon province were collected on the period 1961-1994, which includes the period of the survey. These data are monthly data about the number of cloudy days during the month, the number of rainy days, the maximum daily rain quantity, the average rate of humidity, the minimum daily temperature, the maximum daily temperature during the month. Using these data, we first estimate a VAR model. Computing likelihood ratio tests as well as other information criteria like the Akaike Information criterium or the final prediction error, we choose to estimate a VAR model of order 3 with the 12 month lag included. The results of the VAR model are Table 3. The fit of each equation varies from an R^2 of 21% for maximum rain to an R^2 of 62% for maximum temperature. This shows that there is a substantial variation in weather which is not easily predicted and that weather shocks are relatively important in that environment. For example, the number of days of rain per month varies substantially. On average it is 17.9 days per month but with a standard deviation of 6.37. Moreover, more than half of such variance cannot be explained by our VAR model. Weather shocks are thus quite important in the Bukidnon context, since rain and temperature vary substantially and that a large part of this variation is not simply due to predicted seasonal variations.

2.4. **Agricultural Labor Income.** Households in these data are seen to derive income from a variety of sources. All of the households in the sample are agriculturalists, and cultivate some land. Typically this sort of cultivation will involve labor from several members of the household, so that it's not possible to reliably attribute income or production from cultivation to a particular individual.

We're interested in the question of whether individuals may be somehow compensated for their contributions to the pooled resources of the household, and for this we need some measure of individual contribution. One component of total household income can be ascribed to individuals; that's earnings from agricultural labor. By "agricultural labor" note that we mean labor on *other* farms, compensated either in cash or in kind. Twenty-three percent of the individuals in the sample obtain some income from such labor in at least one of the four rounds, though in any given round only around thirteen percent of individuals are so engaged.

Isn't there a variable describing what share of agricultural income is given to the household?
Maybe a table describing different sources of income for the household?
Maybe a table giving some characteristics which predict

Variables	$cloud_t$	$mxrain_t$	$rainydays_t$	$humid_t$	$mintemp_t$	$maxtemp_t$
$cloud_{t-1}$	0.0283	-5.879***	-0.885**	0.0257	-0.0318	0.0935
	(0.0737)	(1.871)	(0.357)	(0.226)	(0.0433)	(0.0625)
$cloud_{t-2}$	0.340***	-0.448	0.284	0.0444	-0.00328	0.0986
	(0.0713)	(1.810)	(0.346)	(0.219)	(0.0419)	(0.0605)
$cloud_{t-3}$	0.131*	0.160	0.209	-0.110	0.0324	0.0642
	(0.0736)	(1.868)	(0.357)	(0.226)	(0.0432)	(0.0624)
$cloud_{t-12}$	-0.180***	-1.950	-0.934***	-0.570***	-0.0780**	0.144**
	(0.0671)	(1.705)	(0.325)	(0.206)	(0.0395)	(0.0570)
$mxrain_{t-1}$	0.000558	-0.0409	0.00785	-0.00779	-0.00106	0.00450**
	(0.00247)	(0.0627)	(0.0120)	(0.00758)	(0.00145)	(0.00209)
$mxrain_{t-2}$	-3.68e-05	0.0133	-0.0158	0.00727	-0.000920	0.000393
	(0.00251)	(0.0636)	(0.0121)	(0.00770)	(0.00147)	(0.00213)
$mxrain_{t-3}$	0.00252	0.0100	0.0155	0.00917	0.00233	-0.00372*
	(0.00249)	(0.0632)	(0.0121)	(0.00764)	(0.00146)	(0.00211)
$mxrain_{t-12}$	0.00166	0.0327	-0.00239	-0.00382	0.00203	0.00189
	(0.00256)	(0.0649)	(0.0124)	(0.00785)	(0.00150)	(0.00217)
$rainydays_{t-1}$	0.00513	0.715	0.303***	0.0245	-0.000978	-0.0200
	(0.0180)	(0.457)	(0.0872)	(0.0552)	(0.0106)	(0.0153)
$rainydays_{t-2}$	0.0189	0.0177	0.0993	-0.00737	0.000411	-0.0210
	(0.0183)	(0.465)	(0.0888)	(0.0563)	(0.0108)	(0.0155)
$rainydays_{t-3}$	-0.00357	0.969**	0.134	0.0320	-0.0165*	-0.0164
	(0.0169)	(0.430)	(0.0822)	(0.0520)	(0.00996)	(0.0144)
$rainydays_{t-12}$	0.0167	0.931**	0.348***	0.0941*	0.0208**	-0.00800
	(0.0168)	(0.426)	(0.0813)	(0.0515)	(0.00985)	(0.0142)
$humid_{t-1}$	-0.0313	0.759	-0.148	0.547***	-0.00158	-0.0148
	(0.0267)	(0.679)	(0.130)	(0.0821)	(0.0157)	(0.0227)
$humid_{t-2}$	-0.0281	-0.0540	-0.0707	0.102	-0.00934	0.0280
	(0.0302)	(0.767)	(0.147)	(0.0928)	(0.0178)	(0.0256)
$humid_{t-3}$	0.000389	0.0913	-0.0445	-0.0969	-0.0208	0.00951
	(0.0261)	(0.662)	(0.126)	(0.0800)	(0.0153)	(0.0221)
$humid_{t-12}$	0.00144	-0.452	-0.0744	0.112*	-0.00599	0.0217
	(0.0202)	(0.513)	(0.0979)	(0.0620)	(0.0119)	(0.0171)
$mintemp_{t-1}$	0.234**	7.109***	1.876***	0.413	0.560***	-0.247***
	(0.106)	(2.685)	(0.513)	(0.325)	(0.0621)	(0.0897)
$mintemp_{t-2}$	-0.0925	-2.158	0.239	0.174	0.102	-0.165
	(0.120)	(3.055)	(0.583)	(0.370)	(0.0707)	(0.102)
$mintemp_{t-3}$	-0.217**	-6.073**	-1.405***	-0.345	-0.0275	0.182**
	(0.106)	(2.695)	(0.515)	(0.326)	(0.0624)	(0.0901)
$mintemp_{t-12}$	0.297***	6.200***	1.132***	0.345	0.213***	-0.0465
	(0.0904)	(2.294)	(0.438)	(0.277)	(0.0531)	(0.0767)
$maxtemp_{t-1}$	-0.215**	2.626	0.195	0.706**	0.136**	0.300***
	(0.0946)	(2.402)	(0.459)	(0.291)	(0.0556)	(0.0803)
$maxtemp_{t-2}$	0.126	-1.840	-0.428	0.280	-0.0631	0.0234
	(0.0994)	(2.523)	(0.482)	(0.305)	(0.0584)	(0.0843)
$maxtemp_{t-3}$	0.122	2.193	0.808**	0.0622	-0.0836*	0.0211
	(0.0845)	(2.146)	(0.410)	(0.260)	(0.0497)	(0.0717)
$maxtemp_{t-12}$	0.0478	-0.885	0.117	-0.589**	0.0834*	0.491***
	(0.0758)	(1.924)	(0.367)	(0.233)	(0.0445)	(0.0643)

As agricultural productivity is usually importantly affected by the quantity of rain, it is not surprising that off farm labor earnings may vary substantially according to weather shocks and in particular according to the number of rainy days.

In order to separate the predictable and seasonal variations of weather from the unpredictable weather shocks, we use the results of the VAR model to construct a predicted and unpredicted measure of each weather variable w_{kt} for measure k at period t. We denote by w_{kt}^{p} the predicted measure of current weather variable.

Then, we use these measures to disentangle the predicted and unpredicted wage earnings shocks by survey round. However, as Foster and Rosenzweig (1996) show, agricultural earnings in this region are related to the physical productivity of workers and thus to their anthropometric characteristics in addition to education and age. We thus take into account these factors in explaining wage earnings in addition to the part of earnings that can are related to predictable weather variations. We do this by regressing the log earnings $\log y_{it}$ of each individual i at period t on a set of individual characteristics like gender, education level, age, age square, height and height squared, weight and weight squared plus predicted weather variations interacted with village dummy variables and gender dummies (to allow weather variation to affect earnings of males and females differently). The total R^2 of this regression is 23 per cent. Results of such estimation is presented in Table **XXX**. A joint F test that all predicted weather variables do not affect earnings rejects strongly the null (F(43, 1680) = 7.57). Concerning individual characteristics, education and age are the main determinants of earnings.

3. FULL RISK SHARING WITHIN THE HOUSEHOLD

Consider a household having n members, indexed by $i = 1, 2, \dots n$, where an index of 1 is understood to refer to the household head. Time is indexed by $t = 0, 1, \dots T$, where T may be infinite. During each period, member i consumes a K-vector of goods $c_{it} = (c_{it}^{1}, \dots, c_{it}^{K})$. 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 (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 $\alpha_i \in (0,1]$,[2] 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

[2]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.

head given the current state, and let this function satisfy

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

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 **??** 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 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

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

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 $(c^1,\ldots,c^K)$, we parameterize the utility of person i from food consumption at date t by

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

Here $(\gamma,\delta,\theta_1,\ldots,\theta_K)$ 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. EMPIRICS

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) **?** 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:

$$(6)\quad H(p,x,b_1,\ldots,b_n,w) = \max_{\{(c_i,a_i)\}_{i=1}^n} \sum_{i=1}^n \alpha_i \left(U(c_i,b_i) + Z_i(a_i,b_i)\right)$$

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

subject to the budget constraint

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

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_k^i of good k in person i, given the current state (p,x,b,w) and the activities $(a_1,\ldots,a_n)$ undertaken by the household. Differentiating the second term of the Bellman equation (6) with respect to c_k^i gives

$$R_i^k(p,x,b_1,\ldots,b_n,w,a_1,\ldots,a_n) \equiv$$

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

Then first order conditions from the nutritional investment problem include

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

for $i = 1, \ldots, n$ and $k = 1, \ldots, K$, 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. Results

5.1. **Results on Nutritional Investment.** Here, for tests involving the relationship between the individual characteristics b_{jt} and quality adjusted prices, we use a set of logarithms of time-varying individual characteristics $\Delta \log \zeta_{it}$, which include a set of (quarterly) time effects; interactions between sex and the logarithm of age in years, 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 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. We also use a single fixed individual characteristic, the person's sex.

Table 4 reports results of projecting changes in different measures of quality adjusted prices (using both the changes in the unit cost per Calorie and in the unit cost per gram of protein).

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 (**??**) are all transformed in such a way that the estimated coefficients can be interpreted 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. Estimated elasticities associated with the cost per gram of protein are less dramatic, but also significantly different from one. Further, the coefficients associated with the costs of both Calories and protein are jointly significant (the final column of Table 4 reports the F-statistics associated with the joint test of the hypothesis that both coefficients are zero, with p-values in parenthesis).

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 collective regime nor the pure incentive regime describes the mechanism used to assign food quality in the Philippine setting which generated our data.

	Calorie cost	Protein cost	F (p-value)	Calorie cost	Protein cost	F (p-value
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: Male	3.8164*	1.8719*	1615.2035	3.8142*	1.8742*	1612.333
	(0.1087)	(0.0365)	(0.0000)	(0.1087)	(0.0366)	(0.0000
$\frac{\theta'\upsilon_1}{\theta'\upsilon_i}$: Female	1.5882*	1.0857*	470.3805	1.5886*	1.0882*	471.385
	(0.0985)	(0.0381)	(0.0000)	(0.0985)	(0.0381)	(0.0000
$\frac{\delta}{\theta'\upsilon_i}$: Age male	0.0036*	−0.0183	10.1705	0.0041*	−0.0120	10.093
	(0.0017)	(0.0257)	(0.0000)	(0.0018)	(0.0264)	(0.0000
$\frac{\delta}{\theta'\upsilon_i}$: Age female	0.0000	0.0140	0.2853	0.0005	0.0190	0.288
	(0.0020)	(0.0297)	(0.7518)	(0.0020)	(0.0303)	(0.7498
Days sick, male	0.0001*	0.0009	5.4003	0.0001*	0.0009	5.351
	(0.0000)	(0.0006)	(0.0045)	(0.0000)	(0.0006)	(0.0048
Days sick, female	0.0000	0.0010	1.1505	0.0000	0.0010	1.083
	(0.0001)	(0.0008)	(0.3165)	(0.0001)	(0.0008)	(0.3385
Pregnant	0.0003	−0.0016	0.1688	0.0003	−0.0032	0.240
	(0.0011)	(0.0159)	(0.8447)	(0.0011)	(0.0160)	(0.7862
Nursing	−0.0000	−0.0007	0.1451	0.0000	−0.0006	0.141
	(0.0001)	(0.0019)	(0.8649)	(0.0001)	(0.0019)	(0.8677
Second quarter	0.0004	0.0048	1.1122	−0.0001	−0.0094	0.962
	(0.0003)	(0.0039)	(0.3289)	(0.0007)	(0.0101)	(0.3819
Third quarter	−0.0007*	−0.0112*	4.0745	−0.0008*	−0.0130*	5.040
	(0.0003)	(0.0040)	(0.0170)	(0.0003)	(0.0042)	(0.0065
Fourth quarter	0.0011*	0.0147*	8.0336	0.0009*	0.0112*	4.143
	(0.0003)	(0.0041)	(0.0003)	(0.0003)	(0.0047)	(0.0159
y^p_{1t+1}	—	—	—	0.0004	0.0528	1.077
	—	—	—	(0.0037)	(0.0547)	(0.3403
y^u_{1t+1}	—	—	—	−0.0002	−0.0122	1.841
	—	—	—	(0.0006)	(0.0084)	(0.1587
y^p_{it+1}	—	—	—	0.0030	0.0289	0.624
	—	—	—	(0.0027)	(0.0406)	(0.5356
y^u_{it+1}	—	—	—	0.0003	0.0094	0.581
	—	—	—	(0.0006)	(0.0095)	(0.5589

TABLE 4. Changes in the allocation of food quality.

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 nutrional 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.

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