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# FARM PROFITS, PRICES AND HOUSEHOLD BEHAVIOR

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**ABSTRACT**

The farm household model, in which decisions about production and consumption are made simultaneously, lies at the heart of many models of development. Empirically modelling these simultaneous choices is not straightforward. The vast majority of empirical studies assume that farm households behave as if markets are complete in which case decision-making simplifies to a recursive system where consumption choices can be treated as if they are made after all production decisions. Previous empirical tests of this assumption have relied on restrictions on production decisions. We develop a new approach to testing based on household consumption choices and implement the procedure using data from rural Indonesia. Relative to production-side tests, the consumption-based test is well-suited to identifying those farm households in any setting whose behavior is consistent with complete markets and those for whom the assumption is rejected. We find the recursion assumption is not rejected for larger farmers but is rejected for small farmers. The tests are straightforward to implement and the results of the tests provide new opportunities to identify the behaviors that households adopt in the face of incomplete markets.

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## 1. Introduction

The agricultural household model has played a central role in many empirical and theoretical studies of economic development. The model, which dates back at least to Chayanov (1966), integrates production of goods that are consumed by a farm-household into a standard utility maximization framework and has been used to provide important insights into a broad array of economic questions. These include, for example, links between nutrition and labor markets (Strauss, 1982, 1984; Thomas et al., 2016), wage determination, labor supply and agricultural productivity shocks (Rosenzweig, 1980; Kochar, 1999; Jayachandran, 2006; Kaur, 2019, Breza et al., 2019), risk and human capital invesments (Jacoby and Skoufias, 1997), the allocation of resources among family members (Udry, 1996; Duflo and Udry, 2004; Edmonds and Theoharides, 2019; Rangel and Thomas, 2019), property rights (Field, 2007), technology adoption (Barnum and Squire, 1979; de Janvry, Fafchamps and Sadoulet, 1991; Conley and Udry, 2010; Suri, 2011, Jones et al., 2019) and microcredit and financial markets (Kaboski and Townsend, 2011; Beaman, Karlan, Thuysbaert and Udry, 2015).

A central assumption in the model is that farm households make decisions as if markets are complete which underpins the extremely powerful result that the simultaneous production and utility maximization problem can be modeled recursively with farm profit maximization occuring in a first stage without reference to decisions about consumption of goods and leisure. In the second stage, farm households maximize utility treating profits from the production side as given (Singh, Squire and Strauss, 1986). This separation of consumption and production decisions has important implications for studies of farm households: on the one hand, production decisions can be analyzed independently of preferences; on the other hand, consumption choices can be examined without taking into account how resources are allocated in the farm business. To wit, the recursion or separation assumption is invoked, in many cases implicitly, in much of the theoretical and empirical literature in development.

It would be fatuous to assert that low income, rural settings are in fact characterized by a complete system of markets. There is, however, a good deal of evidence that farm households organize their economic and social lives in ways that provide the resources necessary to make the best choices for them and their families, adapting their behaviors to take into account missing markets (Barnum and Squire, 1979). For example, families and communities share risk by providing insurance and resources in times of need (Rosenzweig, 1988; Rosenzweig and Stark, 1989; Townsend, 1994), are able to successfully smooth seasonal variation in income (Paxson, 1992, 1993), make choices that mitigate liquidity constraints (Rosenzweig and Wolpin, 1993, Zimmerman and Carter, 2003), and that families are extremely resilient even in the face of large-scale unanticipated natural disasters and financial shocks (Frankenberg, Smith and Thomas 2003; Stillman and Thomas, 2008; Frankenberg et al., 2018). However, it would be premature to interpret this evidence as indicating that all farm households in the studied rural economies behave as if production and consumption are recursive. Recent evidence highlights heterogeneity in the behavioral choices of households within rural economies and that the lack of markets deleteriously affects the well-being of poorer and less connected households (Chandrasekhar, Kinnan and Larreguy, 2018; Thomas et al., 2004; Banerjee et al., 2019).

To this end, we develop and implement a novel approach to testing for recursion that is designed to yield more powerful evidence than in the existing literature and identify those sub-groups of households within a community whose behavior indicates they face the greatest constraints. Tests for recursion in the literature have been based on implications for farm household production decisions. There are two classes of these tests. First, seminal work by Benjamin (1992) and Pitt and Rosenzweig (1986) pointed out that input choices or profits can be treated as independent of farmer and household characteristics. (See, for example, Udry, 1999; Bowlus and Sicular, 2003; LaFave and Thomas, 2016; Dillon and Barrett, 2017; Dillon et al., 2019, for applications.) Second, a more structural approach has estimated the marginal productivity of each input into the farm production function and compared estimates of these implicit prices with market-level prices (Jacoby, 1993; Lambert and Magnac, 1998; Barrett et al., 2008).

Whereas the earliest tests failed to reject recursion, some recent evidence indicates that the assumption is rejected. However, empirical implementation of production-side tests has proved to be far from straightforward. These tests typically impose strong assumptions that are difficult to test, have had to confront substantial measurement challenges and have difficulty purging estimates of contamination due to unobserved heterogeneity and behavioral responses of farm households.

This paper makes three contributions. First, we develop a consumption-side test that exploits the fact that, under recursive two-stage budgetting, factors that affect only farm business profits in the first stage are restricted, in the second stage, to only have an income effect on consumption choices. Such factors include, for example, prices of inputs into farm production that have no direct influence on consumption choices. The tests are implemented using longitudinal survey data from the Work and Iron Status Evaluation (WISE) conducted in Central Java, Indonesia which collected detailed information about consumption at the household level in conjunction with transaction prices elicited from local markets, shops, and stalls in the WISE communities.

Second, we establish that the consumption-side tests are, in principle, straightforward to implement and not subject to an array of specification concerns that arise with production-side tests. Third, in part because of this advantage of the consumption-side tests, we provide evidence that rejection of recursion is not universal, but farm households that have greater landholdings behave as if they face a complete set of markets. This is an important methodological result: it demonstrates the consumption-side test has the power to detect heterogeneity among farmers within the same community, facing the same set of prices, yet behaving differently. Production-side tests using the same data failed to draw these distinctions (LaFave and Thomas, 2016). The result is also substantively important as illustrated by evidence on differential smoothing behavior in the face of income and price innovations of households for whom production and consumption decisions are recursive relative to those for whom they are not.

The next section presents a dynamic version of the neoclassical agricultural household model appropriate for our longitudinal data and focuses on the implications of recursion for consumption allocations. The empirical demand system is outlined in Section 3, and the survey and price data are discussed in Section 4. Section 5 presents the results for the full sample of households as well as heterogeneity across households in the same community. Section 6 concludes with a discussion of the implications of our findings.

## 2. Tests for recursion: theory

The following describes a dynamic version of the agricultural household model along with the restrictions on production that are implied if consumption and production decisions are recursive in each period. We then lay out the implications for consumer demand by the farm household and develop empirically-tractable non-linear Wald tests.

### *2.1 Dynamic model of the agricultural household*

Assume that a farm household chooses consumption and leisure in each season or time period, *t*, to maximize the present discounted value of expected current and future utility subject to a production process, endowment of time, and intertemporal budget constraint. If preferences are intertemporally additively separable, households choose consumption goods, farm inputs, and leisure to:

$$max\ E\left[\sum_{t=1}^{T}\beta_t^t u\left(x_{mt}, x_{ct}, \ell_t; \mu_t, \varepsilon_t\right)\right] \qquad [1]$$

subject to:

$$Q_{ct} = Q_{ct}(L_{ct}, V_{ct}, A_{ct};\ \nu_{ct}) \qquad [2]$$

$$E_{it}^{L} = L_{it}^{F} + L_{it}^{O} + \ell_{it} \qquad [3]$$

$$W_{t+1} = \left(1 + r_{t+1}\right)[W_t + \left\{\sum_i w_{it}(E_{it}^{L} - \ell_{it})\right\} +$$
$$\left\{\sum_c p_{ct}Q_{ct} - w_t L_{ct} - p_{vt}V_{ct} - p_{At}A_{ct}\right\} - \left\{p_{mt}x_{mt} + p_{ct}x_{ct}\right\}] \qquad [4]$$

where $\beta_t$ is the discount rate, $x_{mt}$ is a vector of market consumption goods, $x_{c\,t}$ is consumption of agricultural goods (i.e. food, some of which may be grown by the household), and $\ell_t$ is a vector of household members' leisure. Preferences are captured by $\mu_t$ and $\varepsilon_t$, which include observed and unobserved characteristics that parameterize the utility function such as household size and composition. There is an agricultural production function, [2], for each crop $c$ in each time period, $Q_{ct}$, which relates labor, $L_{ct}$, variable inputs such as seed and fertilizer, $V_{ct}$, and capital stocks, including farm land, $A_{ct}$, to output of that crop in each period. Crop and time-specific productivity shocks are represented by $\nu_{ct}$. Some of the crop output may be consumed by the household, as part of $x_{ct}$ in [1], and some may be sold on the market at price $p_{ct}$. The total endowment of time available to each household member $i$, $E_{it}^{L}$, is allocated between working in the family business, $L_{it}^{F}$, outside the family business, $L_{it}^{O}$ and leisure, $\ell_{it}$. Total household time is the sum of these endowments over all members, $i$=1...N, $E_t^L = \sum_i E_{it}^L$. Households face uncertainty over the realization of future prices and productivity shocks.

The household intertemporal budget constraint, [4], describes the evolution of wealth over time. In the presence of credit markets or some other mechanism for inter-temporal smoothing, farmers can borrow resources in period $t$ to be repaid with interest at the market rate $r_{t+1}$ in the following period and a parallel market exists for savings which earn the same market interest rate. Wealth in period $t+1$ is equal to the interest earned on wealth in $t$ plus net savings that period. Net savings by the household in period $t$ are the sum of total income from all work (in the first pair of braces) and farm profits (in the second pair of braces), less expenditure (in the third pair of braces). Wealth is negative if a household is in debt. Each household member who works earns wage income from off-farm labor at the market wage for that member, $w_{it}$, which, under the assumption of the model, is also the shadow wage for work by that member on the farm. Thus, the imputed value of labor supplied by household member $i$ to their own business and to the market is $w_{it}(E^L_{it} - \ell_{it})$. Net profit is given by the sum over all crops of total output $Q_{ct}$ evaluated at the market price, $p_{ct}$, less the imputed value of labor demand (at the market price), $w_t L_{ct}$, and the costs of variable and fixed inputs, $p_{vt}V_{ct}$ and $p_{at}A_{ct}$, respectively. The value of consumption, in the final pair of braces, is total spending on goods and services purchased in the market, $p_{mt}x_{mt}$, and the value of consumption of own production evaluated at the market price, $p_{ct}x_{ct}$.

Solving [1] through [4], demand for market, $x_{mt}$, and home–produced goods, $x_{ct}$, depends on all prices of market goods, output prices of home produced goods, all input prices in the production function, $p_{mt}$, $p_{ct}$, $p_{vt}$ and $p_{At}$, respectively, the shadow value of time of each household member, $w_{it}$ and non-labor income (or income from wealth, $r_t W_t$), $y_t$, given observed household characteristics, $\mu_t$, such as demographic composition and unobserved characteristics, $\varepsilon_t$, such as preferences:

$$x_{gt} = x_{gt}(p_{mt}, p_{ct}, \; p_{vt}, p_{At}, w_{it}, y_t \; ; \; \mu_t, \varepsilon_t) \qquad [5]$$

where market and home produced goods are collected together and denoted $x_{gt}$,. Under the assumption of additive inter-temporal separability, prices of all but the current period only affect current demand through the impact on the marginal utility of income which is absorbed in $\mu_t$.

As discussed in Singh et al., (1986) and formally established in Strauss (1986) for the static framework and Udry (1999) for the dynamic model, if all current and future prices can be treated as given (that is, if all current and future markets for state-contingent goods exist and are competitive), then the optimization program [1]-[4] can be recast as a two-stage choice problem in which, in each period, the farm household chooses allocations that maximize profits in the farm business without taking into account consumption choices in [1].[1] Conditional on these allocations, the household maximizes welfare. The insight that production choices do not depend on preferences and, therefore, household characteristics only enter [1] has been the foundation for all tests of recursion in the literature. The next sub-section develops a test for recursion that complements these production-side tests with consumption-side tests for recursion.

[1] Under these assumptions, separation holds if production choices in period $t$ are made prior to output and price realizations in that period (Udry, 1999). This is likely to be the case in most agricultural settings and is the case in the setting for this study.

## *2.2 Consumption-side tests for recursion*

In each period of the recursive model, farm households maximize profits, $\pi_t$, in their businesses without taking into account preferences. The farm household chooses labor, variable inputs, and capital given the production technology and all input and output prices set by the market including the price of own labor:

$$\max_{L,V,A} \ \pi_t = \sum_c p_{ct} Q_{ct}(L_{ct}, V_{ct}, A_{ct};\ \nu_{ct}) - w_t L_{ct} - p_{cvt} V_{ct} - p_{At} A_{ct} \qquad [6]$$

which yields input demand functions that depend only on current market prices. In principle, it is straightforward to allow expected future prices to enter production choices in which case input demands will also depend on those prices. This would arise, for example, if there are current price shocks because of, say, weather, trade or manufacturing shocks that cause some inputs to be relatively expensive relative to their long run price trajectory; it would also arise if future relative prices or future technologies are expected to change such as the introduction of new seed varieties. In these cases, input demand functions depend on current and expected future market prices for all inputs. Substituting the input demand functions yields the profit function for all crops taken together:

$$\pi_t^* = \pi_t^*(p_{c\tau},\ w_\tau,\ p_{v\tau},\ p_{A\tau}) \qquad [7]$$

where τ denotes current period, *t*, and all future periods and, for future periods, prices represent their expected future values at time *t*.

The farm household maximizes the present discounted value of expected utility [1] subject to the budget constraint modified to take into account the fact that the household treats profits from the first stage, $\pi_t^*$, as given:

$$W_{t+1} = \left(1 + r_{t+1}\right)[W_t + \left\{\sum_i w_{it}(E_{it}^L - \ell_{it})\right\} + \left\{\pi_t^*(p_{c\tau}, w_\tau, p_{v\tau}, p_{A\tau})\right\} - \left\{p_{mt}x_{mt} + p_{ct}x_{ct}\right\}] \qquad [8]$$

and thus demand for each good, *g*, depends on profits, rather than all of its determinants, which are treated in the optimization program the same as any other sources of non-labor income:

$$x_{gt} = x_{gt}(p_{mt},\ p_{ct},\ \ w_{it}, \pi_t^*(p_{c\tau}, w_\tau, p_{v\tau}, p_{A\tau}), y_t\ ;\ \mu_t, \varepsilon_t) \qquad [9]$$

The key insight is that, under the recursivity condition that farm households behave as if production decisions can be made prior to consumption choices, farm business choices affect utility maximization and consumption allocations only through the shift in the budget constraint given by the value of farm profits. Thus, second stage utility maximization yields conditional demand functions that depend on prices of consumption goods, including the value of time, income and the marginal utility of wealth that parallel demand functions in standard models of consumer behavior without production.

This insight, and inspection of demand [9], provides the intuition for a consumption-side test of recursion: prices that enter the profit function and have no direct impact on demand will only affect demand through an income effect. This applies to the vectors of current and future prices of variable and fixed inputs in farm production, $p_{v\tau}$ and $p_{A\tau}$, respectively in the model. Both leisure, which is valued at the market wage, and farm output, priced at its opportunity cost, the market gate price, directly affect demand and so estimated effects on demand reflect the combination of the change in the price and the impact on profits. If some of the farm products are never consumed by the household, the prices of those cash crops are also weakly separable from other output prices and, like inputs, only affect demand through an income effect yielding additional testable restrictions on the demand functions.

Exploiting this result, differentiating [9], the marginal effect of a change in any one of these prices, $p_{v_1}$, on demand for *g* can be decomposed into two parts: the effect of a change in the price on profits, and the impact of a change in profits on consumption:

$$\frac{\partial x_g}{\partial p_{v_1}} = \frac{\partial x_g}{\partial \pi^*}\frac{\partial \pi^*}{\partial p_{v_1}} \qquad [10]$$

where, without loss of generality we focus on the price of one variable input into farm production and the time subscripts are suppressed for expositional simplicity. Clearly [10] does not yield a testable restriction for recursion. However, with the prices of two farm inputs, without loss of generality, $p_{v1}$ and $p_{v2}$, that affect demand only through the profit function, the ratio of their effects on demand is

$$\frac{\dfrac{\partial x_g}{\partial p_{v_1}}}{\dfrac{\partial x_g}{\partial p_{v_2}}} = \frac{\dfrac{\partial x_g}{\partial \pi^*}\dfrac{\partial \pi^*}{\partial p_{v_1}}}{\dfrac{\partial x_g}{\partial \pi^*}\dfrac{\partial \pi^*}{\partial p_{v_2}}} = \frac{\dfrac{\partial \pi^*}{\partial p_{v_1}}}{\dfrac{\partial \pi^*}{\partial p_{v_2}}} \qquad [11]$$

Since, the income effect, $\frac{\partial x_g}{\partial \pi^*}$, is the same for all prices that are weakly separable in the demand for

$g$, the ratio of the price effects is independent of the good $g$ as shown in the final term in [11]. Thus, if the model is recursive, the ratio of the effects of any two prices that only affect profits is the same for all goods in the demand system [9]. This is the core of the consumption-side test for recursion.

Specifically, it follows from [11] that for all pairs of goods, $g_j$ and $g_k$ in the demand system:

$$\frac{\dfrac{\partial x_{g_j}}{\partial p_{v_1}}}{\dfrac{\partial x_{g_j}}{\partial p_{v_2}}} = \frac{\dfrac{\partial \pi^*}{\partial p_{v_1}}}{\dfrac{\partial \pi^*}{\partial p_{v_2}}} = \frac{\dfrac{\partial x_{g_k}}{\partial p_{v_1}}}{\dfrac{\partial x_{g_k}}{\partial p_{v_2}}} \qquad \forall\ j, k \in G \qquad [12]$$

The equality of the ratio of effects of input prices across goods in the demand system in [12] amounts to a series of non-linear Wald tests.

This approach to testing whether farm household decisions are recursive has at least three advantages over production-side tests. First, empirical estimation of production functions is notoriously difficult since inputs are chosen and properly treated as endogenous. This is especially complicated in low income settings where some important inputs, such as organic fertilizer or water, are often not sold on the market and so shadow prices need to be estimated. Studies seldom attempt to measure the effect of these inputs on profits. An advantage of consumption-side tests is that they do not rely on measurement of these prices.

Second, in many settings, farm households produce multiple products and often inter-crop; specifying and estimating separate production functions for each crop is difficult as is the allocation of inputs to each crop. Most studies restrict attention to one or a small number of primary crops. This has no impact on consumption-side tests which rely only on measurement of prices of at least two inputs used in production of any crops.

Third, measurement of inputs poses substantial challenges as does measurement of profits. For example, measurement of land fertility and quality as well as labor quantity and quality is extremely difficult. Most studies that test recursion have treated all labor as homogenous although there is abundant evidence that assumption is rejected. These concerns do not affect the consumption-side tests.

## 3. Tests for recursion: Empirics

The consumption-side tests of recursion are based on empirical estimates of the farm-household demand system. We test for the presence of separation of consumption and production in each period using longitudinal data to account for unobserved heterogeneity that may otherwise contaminate inferences. Following the literature, we estimate an extension of the Almost Ideal Demand System (Deaton and Muelbauer, 1980) in which the share of the budget spent on each good, $g=1,\ldots G$, in the system by household $h$ in local market $m$ at time $t$, $\omega_{ghmt}$, depends on the logarithm of per capita farm expenditure ($PCE_{ht}$) in a flexible way (represented by the function, $f$, Banks et al., 1997) along with the logarithm of a vector of all consumption prices, $p_{\gamma mt}$ ($\gamma=1,\ldots G$), and wages, $w_{mt}$, (which is also vector-valued and measured at the local market $m$ level for different types of labor). The model is extended to also include the logarithm of prices of goods that only affect demand through profits which, in our case, are inputs into the production of crops, $p_{vmt}$. In our setting, no crops are pure cash crops; without good information on farmers' expectations about the evolution of future prices, we do not include those prices in the main specification of the empirical model.[2] Household characteristics that affect demand are captured in the vector, $z_{ht}$, which includes, for example, household demographic composition and human capital of household members. Thus, the empirical model of the share of the budget spent on each good, $g=1, \ldots G$ is:

$$\omega_{ghmt} = f_g(\ln PCE_{ht}) + \ln p_{\gamma mt}\beta_{g\gamma} + \ln w_{mt}\beta_{gw} + \ln p_{vmt}\beta_{gv} + z_{ht}\beta_{gh} + \lambda_{hm} + \varepsilon_t + \varepsilon_{ghmt} \qquad [13]$$

In the dynamic model, demand in any period depends on the marginal utility of income which is assumed to be fixed for each household over the five-year study period. The empirical models thus include a farm-household fixed effect, $\lambda_{hm}$, which can be interpreted as a proxy for permanent income so that the effects of lnPCE on budget shares reflect the impact of transitory innovations in resources (Browning, Deaton and Irish, 1985).

The specification with farm household fixed effects has the additional advantage of sweeping out of the model any household-specific heterogeneity that is fixed over time and affects consumer demand. This includes, for example, deviations between local market prices and the prices paid by the household (because of quality differences or quantity discounts, for example) and all time-invariant tastes that affect household budget allocations including, for example, tastes for investments in the future. To the extent that farmsteads are stable over time, the effects also serve to capture fixed characteristics of the local market $m$ including distance and thus transport costs from the primary markets in the study site. The models also include time effects to take into account seasonal price variation. Time-varying, good specific tastes are captured in $\varepsilon_{ghmt}$.

[2] Expectations of future rice prices are solicited from each farmer in every survey wave. When included in the models, expected future prices do not significantly predict budget shares and none of the conclusion about completeness of markets are affected.

The non-linear Wald statistics to test recursion from [12] are written in terms of the coefficient estimates as:

$$\frac{\beta_{g_j v_y}}{\beta_{g_j v_z}} = \frac{\beta_{g_k v_y}}{\beta_{g_k v_z}} \quad \forall\ j, k \in G,\ \ y, z \in V \qquad [14]$$

for each pair of goods, *j* and *k*, in *G* and for each pair of input prices, *y* and *z*, in *V*.[3] In this ratio form, these tests are not well-behaved when the denominator is close to zero and so we follow Gregory and Veall (1985) and specify the test in product form:

$$\beta_{g_j v_y} * \beta_{g_k v_z} = \beta_{g_k v_y} * \beta_{g_j v_z} \qquad \forall\ j, k \in G,\ \ y, z \in V \qquad [15]$$

It is important to note that [15] should hold for each pair of goods and pair of farm inputs. Failure of [15] for any pairs implies rejection of recursion. In contrast, the joint test for all consumption goods and input prices is likely to lack power, especially as the number of goods and farm inputs increases in much the same way that the power of Durbin-Wu-Hausman type tests decline as the number of covariates included in the test statistic increases.

## 4. Data

An advantage of the consumption-side tests developed above is that data on consumption are routinely collected in budget surveys across the globe and market-level prices of goods and farm inputs are inexpensive to collect. To illustrate the tests, we use data from the Work and Iron Status Evaluation (WISE), a longitudinal survey of households living in rural Purworejo, a kabupten located along the coast of Central Java, Indonesia (Thomas et al., 2016). About 90 percent of the population of approximately one million in Purworejo is rural and the vast majority of rural households farm rice, the staple in Indonesia. Many of the farms are also engaged in cultivation of market garden produce, such as kangkung, a green leafy vegetable like spinach, as well as fruit, particularly oranges, small and large livestock. Food produced in Purworejo is sold locally and in markets in neighboring Daerah Istimewa Yogyakarta (the special region of Yogyakarta), a major Indonesian city that has a population of over 4 million.

Conducted in conjunction with a randomized iron supplement intervention, WISE is a large-scale population-representative longitudinal survey of farm households, communities and local

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[3] As is apparent from the theory, on their own, the estimated effects farm input prices, $p_{vmt}$, in [13] are not informative about whether decision-making is recursive. If decisions are not recursive, there are no restrictions placed on the price effects in [13].

markets that was conducted between 2002 and 2007. In addition to collecting information on household spending, income and socio-demographic characteristics, we paid particular attention to the collection of high quality, local, monthly price data from 2003 onward including detailed transaction-level price data on both consumer goods and farm inputs from local stalls and shops in each of the study areas as well as from all the markets in Purworejo *kabupaten*.

There are three harvesting seasons each year for rice, the primary crop, and, between 2003 and the first trimester of 2005, farm surveys were conducted every four months. A follow-up survey was conducted in 2007. We use all eight waves of the survey, along with market price survey data collected concurrently.[4]

The longitudinal dimension of the study is critical for assuring that tests are not contaminated by time-invariant unobserved heterogeneity arising, for example, from variation in the distance to the market or land quality. Recall, also, that the inclusion of farm household fixed effects in the models sweeps out the effects of variation in permanent income across farm households and take into account unobserved factors that are fixed over time and affect consumer demand in a linear way, including time-invariant factors that affect farm input and technology choices (such as farmer and farm quality) as well as market prices. It is imperative that benefits of the longitudinal design are not offset by attrition during the 8 waves of the study. WISE is designed to follow all split-off households and, for this research, we include 3,600 baseline farm households plus 229 split-offs that started a farm business in the study area after baseline. We interviewed 95% of the farm households in every survey wave and 98% were interviewed in all but one survey wave. (See Thomas et al., 2016 for more detail on follow-up protocols and attrition.)

### *Consumer demand*

Detailed information on consumption by the farm household is collected in a face-to-face interview with the household respondent who is most knowledgeable about this aspect of the household economy, typically the primary female who is usually the wife of the household head. The consumption module, which has been well-validated and is widely used in surveys in Indonesia, takes approximately 40 minutes to complete. For each of 14 food groups,[5] the survey collects information about spending over the previous week as well as the value of consumption of food

[4] None of the conclusions about recursion are affected by exclusion of the 2007 wave.

[5] The food groups are rice; other staples such as corn; dried goods, such as noodles; meat and fish; vegetables such as kangkung; fruits; tofu and tempe; milk, eggs and other dairy; sugar; oil; spices; beverages; tobacco products; and food prepared out of the home.

produced on the farm or provided in kind. Parallel information is collected about 12 non-food groups, four of which are asked for the prior month (such as utilities) and the rest for the twelve months preceding the survey (such as education and health) because spending on these goods tends to be lumpy.[6] The recall period for each consumption item is based on extensive experience collecting consumption data in Indonesia and balances error from longer recall periods against frequency of purchase. All expenditures are converted to monthly equivalents.

Household spending is aggregated into four sub-aggregates for this research for two main reasons. First, estimation of demand systems with zero expenditures is a substantial challenge and aggregation side-steps the complications of separately modelling decisions by households that never consume a good from those that did not consume the good during the recall period (Deaton, 1986). Second, as the size of the demand system increases, the number of pairwise comparisons to be conducted in the non-linear Wald tests rises rapidly and it is helpful to keep that number manageable to illustrate the method. In principle, the tests can be applied with larger demand systems.

The four sub-aggregates are staple grains (mostly rice), other foods, goods for the home including household and personal care items, utilities, transport and rent and, finally, goods related to human capital investments including education, health and clothing. The definition of each sub-aggregate and budget shares for the sub-aggregates and each of the 26 groups of goods collected in the survey is presented in Appendix Table A1. None of our conclusions depends on the choice of four sub-aggregates in the demand system and results of estimating demand systems with seven, ten, and fourteen sub-aggregates are discussed below.

### *Prices*

Given the centrality of prices in understanding farm household behavior, WISE collected detailed data on market-level prices of standardized goods throughout the study period in order to build a consistent series of monthly prices that are plausibly exogenous to farm household decisions. Specifically, within each study community, at the same time that household surveys were being completed by the household survey team, a separate team of enumerators completed comprehensive surveys of the local community. This included the collection of detailed information on prices of goods and services. The enumerators visited *warungs* (local stalls), *tokos* (shops), and *pasars* (markets)

[6] Monthly spending is asked about utilities and transportation; household items; recreation and entertainment and either monthly rental or, in the case of owner-occupied homes, the estimated rent if the home were to be rented out. Spending over the prior twelve months is asked about clothing; household supplies, furniture and repairs; education; medical costs; ceremonies and gifts; taxes; recreation; and all other expenses.

that were used by respondents in the community. *Warung*s are small stalls in the *desa* (village) that are often run from a home by one person who sells non-perishable items that are bought frequently such as oil, sugar and rice. *Tokos* are more formal and have both perishable and non-perishable items as well as non-food items. *Pasars* usually meet once a week and sell local produce, meat and fish as well as a small number of non-food items. There is a good deal of overlap in the goods that are purchased from *warungs* and *tokos* and so one price instrument was designed for those outlets; goods purchased at *pasars* are different and we designed a separate instrument for those outlets. Taken together, the instruments cover 45 food items and 9 nonfood items which are listed in Appendix Table A2 along with the source of each price in the analysis.

Enumerators completed a separate price survey for up to six *warungs* and up to four *tokos*. The *warungs* and *tokos* were selected after obtaining information from household respondents in the community about where they made purchases including outlets outside the *desa*. In most cases, the price survey covered all outlets mentioned; in those cases in which more than six *warungs* or more than four *tokos* were mentioned by respondents in a community, outlets were randomly selected from the list of all mentioned outlets of that type to meet the target number of outlets. There is effectively one *pasar* that operates in each *kecamatan* (a sub-district) and the *pasar* usually meets once a week. As a result, for the vast majority of communities, only one *pasar* is mentioned. A census of all *pasars* was conducted as part of WISE; we match prices collected from the *pasar* most frequently mentioned by respondents in a community which was, in every case, the *pasar* closest to the *desa*. In the small number of cases in which more than one *pasar* is mentioned, a weighted average of prices (using the proportion of households in a community that mentions a *pasar* as the weight) yields the same results.

There are three important points regarding the price data. First, the price surveys collect information from the locations where respondents in the community purchase goods during the study period. Second, prices are collected for goods that are standardized in terms of quantity and quality to construct a consistent price series that reflects variation in the marketplace. This assures that the price series is not contaminated by quantity discounts or quality variation which is likely to be reflected in transaction prices (or unit values) that would be reported by each farmer. Third, the market-level price surveys are designed to characterize the market prices that farmers in the community face at the time they make purchases. This is important if demand or supply of a good is seasonal as is the case for farm inputs such as seed and fertilizer. Those goods are available at planting and time of fertilizing and we conduct our price surveys at those times, prior to, for example, weather realizations. In sum, since farmer demand is small relative to the size of the market, and all farm inputs are produced outside the study area, it is plausible to treat the prices of farm inputs as exogenous in the models of consumer demand. This assumption would be considerably more difficult to justify if we were to use farmer transaction prices or unit values (Deaton, 1988; McKelvey, 2011). We therefore rely on the market-level price data collected for this research.

The price survey instruments were designed for this research and extensively pre-tested. At each outlet, the enumerator collected transaction prices for specific, standardized consumption items. For each item, the size or quantity and, where applicable, the brand was pre-specified on the survey instrument. For some goods, particularly in markets, prices are the outcome of a negotiation; in those cases, the enumerator purchased the item in order to measure the price a respondent would pay for the good, to the extent possible. For goods that were not sold in specific quantities, such as loose vegetables, the amount purchased was weighed with scales carried by the enumerator. In some instances, a brand, size or quantity was not available; in those cases, the enumerator recorded the price, brand, size and additional identifying information of the closest substitute drawing on an ordered list of substitutes on the survey instrument.

A census of all farm stores in Purworejo *kabupaten* was conducted at the beginning of the study. At the time of planting and fertilizing in each season, the stores that served a particular community were visited to collect prices of agricultural inputs including seeds, fertilizers and insecticides. The price, quantity, quality and brand were recorded for each item.

Up to four expert informants in each community were asked to provide estimates of prices of goods and services in the community; the experts included the *kepala desa* (village leader) and the *ibu PKK (pembinaan kesejahteraan keluarga,* leader of the local women's group). Key for this study, each local expert provided estimates of daily wages for four different types of labor: higher and lower skilled adult males and adult females. For each community and survey month, the median wage of all adult males and the median wage of adult females are used as measures of local area wage rates.

For each community, survey month and good, including farm inputs, the median of recorded transaction prices serves as our best estimate of the local market price. All prices and wages are converted to real values using the regional price index available from Statistics Indonesia, Badan Pusat Statistik (BPS). Prices of consumption goods are combined to form four price aggregates that correspond with the four goods in the demand system. The weight assigned to each price in the computation of the aggregate is based on the share of the budget spent on the item by households in Purworejo who were surveyed in the 2002 wave of SUSENAS, a large scale socio-economic survey that is population-representative at the kabupaten level. In contrast with WISE, which asks about spending on groups of goods, every three years, SUSENAS contains a detailed consumption module with spending and own consumption on over 100 items. Appendix Table A.2 lists the weight assigned to each of the prices and the source of price data used to construct the aggregate price indices.

The first column of Table 1 reports average budget shares, per capita farm household expenditure and socio-demographic characteristics of households. The average farm household spends about Rp 200,000 per household member per month (which was approximately US$20 at the time). Of that, about one-sixth is spent on rice and other grains, 45% on other foods, and 20% each on goods for the home and on human capital related goods.

The second column of Table 1 reports the average log real price indices for the four consumption goods, $p_{ct}$, and average log prices of farm inputs, $p_{vt}$, along with standard errors. Four farm input prices are used in the empirical analyses: the price of IR64 rice seed, a high-yield rice variety that, at the time, was the most commonly cultivated in the region; kangkung seed, a leafy green vegetable similar to spinach that is produced by most farmers; fertilizer and insecticide. These farm inputs are widely purchased, 81 percent of farms report expenditure on seeds and 95 percent purchase fertilizer and insecticides. Additionally, since seeds, fertilizer and insecticide are not consumed, their prices should impact consumption only through a profit effect among farm households that behave as if production and consumption decisions are recursive.

The validity of the test that farm input prices only have income effects will be compromised if it is not possible to identify farm input price effects from the effects of consumption good prices. This would occur if there were no variation in the prices of farm inputs that is independent of variation in the consumption price indices. Because of seasonal effects and local area shocks that affect both prices of consumption goods and farm inputs, consumption and input prices are likely to move together over time, even after taking into account inflation; this covariation is taken into account in the empirical model [13] by the inclusion of time fixed effects. Similarly, prices are likely to systematically vary across communities because of, for example, the distance to markets; the empirical model thus takes community-specific heterogeneity into account so that identification of price effects depends on within-community variation in prices over time.

Conditional on these fixed effects, it is possible to empirically test whether variation in farm input prices can be explained by variation in consumption prices and we find no evidence that farm input prices are significantly correlated with consumption prices. For example, in a model relating the ln(price) of rice seed to the ln(price) of the four consumption goods, none of the effects of consumption prices is substantively large or statistically significant and, taken together, the F test statistic for the four prices is 1.90, (p-value=0.216). The prices that are most likely to be susceptible to this concern are the prices of rice and rice seed; in the model, the coefficient on the ln(price) of rice is 0.011 with a standard error of 0.095. The four consumption goods prices are unable to explain variation in any of the other three farm input prices.

To illustrate the variation in farm input prices that is exploited in the empirical models, Figure 1 displays prices across markets and time for fertilizer. To highlight change over the entire study period, panel A displays the percentage deviation in the price in each market relative to the overall average price, all computed at the start of the study (on the left) and computed at the end of the study (on the right). Each line represents a market and the rank order of each market (from highest to lowest price at baseline) is indicated next to the endpoint of each line. The heterogeneity across markets at baseline is absorbed by the farm fixed effects, and so it is the change in relative prices that identifies the price effects in the models. Variation in relative prices between the start and end of the study are large: the market with the highest price at baseline has the lowest price at the end of the study; the market with the second lowest price at baseline has the highest price at the end of the study. There is also substantial variation in prices both within and across markets during the study period as illustrated in panel B of the figure which displays fertilizer prices for three of the markets. (With more markets, the figure is difficult to read.) There is considerable month to month variation in prices which reflects variation in supply and demand in each market over time. Whereas the prices of fertilizer and insecticide did not keep up with inflation, the prices of rice and kangkung seed rose faster than the inflation rate during this time. The key point is that there is heterogeneity in prices across time and space that is plausibly exogenous from the perspective of an individual farmer in the study area.

We turn next to estimates of [13], present tests for recursion and then investigate whether there are identifiable sub-groups of farm households that behave as if markets are complete.

## 5. Results

### *5.1 Demand System Estimates*

Results of estimating the demand system [13] are reported in Table 2 for the four consumption good sub-aggregates. Panel A reports estimated effects of the logarithm of prices of the consumption goods, $p_{ct}$, on the share of expenditure on a given good and panel B reports estimates of the effects of ln(PCE), specified as a linear spline with knots at each quartile of its distribution. The effects of the logarithm of prices of farm inputs, $p_{vmt}$, are reported in panel C of the table, and the logarithm of community wages, $w_{mt}$, in panel D. All models include farm household fixed effects and date of survey fixed effects (measured in months). Standard errors reported below the estimates are robust to heteroscedasticity and take into clustering at the farm household level. (Standard errors that are clustered at the community level are essentially identical.)

The own-price estimates for human-capital related goods and goods for the home are negative and statistically significant for human-capital related goods. In contrast, the own-price effects for grains and other foods are positive and statistically significant in the case of grains. In the context of the farm household model, as shown in [9], the prices of goods that are both produced and consumed on the farm not only have a direct effect on demand for that good but also affect demand through profits. The estimates suggest that negative own-price effects of grains and of other foods are more than outweighed by the positive profit effects when prices of these goods increase.

The estimated income effects in panel B can be interpreted as the effects of transitory income since the farm household fixed effects absorb the impact of permanent income. The effects are precisely determined and indicate that the share of the budget spent on grains is non-monotonic, rising when lnPCE is below the bottom quartile and declining thereafter. Budget shares tend to rise with PCE for other foods but at a declining rate of increase, fall with PCE for shares spent on goods for the home and increase with PCE, especially above the median, for the share of spending on human capital related goods.

The effects of the logarithm of the four farm input prices are displayed in panel C of the table. Tests for the joint significance of the estimated input price coefficients for each budget share are reported in panel E. Half of the estimated effects of farm input prices are statistically significant and, taken together, the four farm input prices significantly affect each of the budget shares. This is consistent with input prices having a direct effect on demand and an indirect effect through profits.

### *5.2 Tests for recursion*

If farm household decisions are recursive, then the price effects are restricted to operate through the profit effect in which case the ratios of all estimated farm input price effects should be the same following [12] and [14]. To illustrate this test, ratios for the first pair of input prices, fertilizer and rice seed, along with their standard errors calculated using the delta method are reported in panel A of Table 3 for each of the four goods. For example, the ratio of the effect of fertilizer prices (2.27 in panel C of Table 2) to the effect of rice seed prices (0.74) on grain demand is reported in the first column (3.06) along with its standard error (3.49). The corresponding ratios for demand for other food, goods for the home, and human capital are -0.21 (s.e. 0.23), 0.13 (s.e. 0.23), and -2.70 (2.39).

If farm household production and consumption decisions are recursive, these ratios should be the same. Or, by rewriting [14], the ratio of the ratios should be equal to one for all pairwise comparisons. With four goods in the demand system, there are six pairwise ratio comparisons. Panel B of Table 3 reports these relative ratios for each pair of goods and the associated *p*-value in brackets for a test of whether the statistic is equal to one. For example, the other foods to grain ratio, -0.21 to 3.06, is equal to -0.07 and we reject the null of one with a p-value of 0.013, thus rejecting the predictions of recursion. Across all pairs, the test statistics clearly deviate from the null of one and range from -20.77 to 12.86. Four of the six tests are rejected at the 5 percent level. Panel C of Table 3 reports the overall test of equality across all six pairwise ratios which is rejected as well (p-value = 0.027).

The results of these tests for the full demand system are summarized in the lower panel of Table 4 which reports the *p*-values for the non-linear Wald tests for the equality of each of the pairs of ratios. There are 36 pair-wise tests of the equality of ratios when all goods and prices are considered. The first column [1.1] restates the pairwise results for the prices of fertilizer and rice seed from Table 3 in rows 1 through 6 and the combined test in row 7. Columns [1.2] to [1.3] show corresponding results for the remaining pairs of prices.

While rejection of any one of the pairs is evidence against the recursion hypothesis, with a 5% size of test, we expect 2 of the 36 ratios to be significantly different and, with a 10% size of test, 4 of the ratios will be different. In fact, 11 of the 36 ratios (or 30%) are statistically significantly different at a 5% size of test and 15 (or 42%) at a 10% size of test. These cannot be ascribed to chance alone, even after adjusting for multiple testing. The consumption-side tests provide compelling evidence against the recursion hypothesis: overall, farm households in Purworejo do not behave as if markets are complete.[7, 8]

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7 The p–value for the non-linear Wald test for the equality of all 36 ratios in Table 3 is reported in row 8 of the table. This test is likely to lack power because several of the underlying price effects (in panel C of Table 2) are not precisely estimated. The fact that two of the six tests for all ratios for any pair of prices are rejected (at a 10% size of test) in row 7 of the table reinforces this conclusion.

8 Results from larger demand systems including finer disaggregation of goods are consistent with the four-good illustration reported here. A 7 share system with 126 pairwise tests results in 27 rejections at 10%, 10 shares (270 pairwise tests) results in 35 rejections, and 14 shares (546 tests) 99 rejections.

### *5.3 Who behaves as if markets are complete?*

The finding that, overall, farm households in Purworejo do not behave as if markets are complete does not speak to the question of whether some households have organized their social and economic lives so that the choices they make are not distinct from those that would be made if markets are complete. Such households are likely to have greater wealth, better access to credit markets and/or more family ties or social connections that can be a source of insurance. Land is the primary asset in Purworejo and those households who own more land are not only wealthier but also tend to have larger extended families, more social connections, and greater access to financial markets. To test whether these households behave as if markets are complete and those that have less land do not, Table 5 reports the same set of non-linear Wald tests as in Table 4 for two groups of farm households. Results are summarized in the top panel of the table.

Panel B of the table includes those households that have less than the average land holdings for farms in their *desa* (village). These less wealthy farm households account for about two-thirds of all farm households in the sample since the distribution of land holdings is skewed to the right. Panel C includes those households that have more than the average land holdings. These wealthier farm households account for the remaining third of the sample. The stratification is based on land holdings measured at baseline. The corresponding demand system estimates are reported in Appendix Table A3.

For the poorest two-thirds of farm households in panel B, 7 of the 36 pairs of ratios (or 20%) are significantly different from each other at a 5% size of test and 14 of the pairs of ratios (40%) are significantly different at a 10% size of test. The results parallel those for all households and, again, the recursive model is rejected.

However, for the wealthier households, in panel C, none of the pairs of ratios is significantly different from each other at a 5% size of test and equality of the ratios is rejected at a 10% size of test in only one case. Since that is less than would be expected by chance, the evidence for these farm households indicates that they do in fact behave as if they are facing complete markets.

This is an important result for two reasons. First, we have identified a group of households within the study area for whom the recursion assumption is not rejected. Treating consumption choices as if production choices have been made and modelling farm production without regard to preferences is likely to characterize the behaviors of these farm households well. However, for the less wealthy households, the recursive model is not likely to be appropriate.

Second, from a methodological point of view, the consumption-side test provides information about variation within the sample in behavior of farm-households that is not easily uncovered using production-side tests. Previous research with the same data has shown that the model with recursion is rejected using a production-side test. If farm households treat wages as parametric, demand for farm labor should not depend on the composition of the farm household. Using the same data, LaFave and Thomas (2016) show that, in fact, farm labor demand systematically varies with composition. However, that research was unable to uncover robust evidence that sub-groups of the study farm households decisions are recursive.

Over and above identifying households that behave as if markets are complete, these results have the potential to provide insights into the strategies adopted by those households by comparing their behavior with the behavior of all other households. This has been a major challenge in the literature because it is difficult to draw conclusions about constraints on the basis of behavioral choices alone. For example, it is tempting to infer that households who borrow on the market are not liquidity constrained. That conclusion would be premature. On one hand, borrowers would be liquidity constrained if they would like to borrow more. On the other hand, those who do not borrow are assumed to be liquidity constrained (excluded from the market) but they may not need to borrow in which case they are not liquidity constrained. Moreover, even information about interest rates is ambiguous: those who borrow at high interest rates may be the households who have the highest expected return on investment projects.

We focus on one dimension of observed behavior: borrowing against human capital of household members, specifically adult weight and child height. We choose this focus because during the 1998 financial crisis in Indonesia, when GDP declined by 15% in one year, female adults literally tightened their belts as their own weight significantly declined in an effort to protect young children in their families whose nutritional status was unaffected during the financial crisis (Thomas and Frankenberg, 2006; Frankenberg and Thomas, 2018).

Variation during the study period in BMI of female adults in households in the recursive group is compared with variation among female adults in all other households in a regression framework. The model includes an individual fixed effect for each female, to sweep out all time-invariant factors that affect her BMI, as well as a time effect for each wave of WISE to take into account all shared temporal variation due to, for example, seasons and economic fluctuations. The model also includes an indicator that identifies the recursive group of households which is interacted with the time effects so that the differences between the groups of households may vary with each wave. These estimates measure the extent to which there is excess variation in BMI over time among females in households in the recursive group relative to females in all other households. Taken together, these estimated excess variation effects are statistically significant (p-value=0.002) indicating that females in the recursive group are borrowing against their own bodies, specifically their weight, more than is the case among females in the non-recursive group. There is no evidence of similar excess variation in the BMI of males (p-value-0.34) or excess variation in the height of young children (p-value=0.30) in the households that behave as if production and consumption are recursive.

The evidence indicates that households in the recursive group use human capital of females to fill in for missing markets and so there is excess cycling of weight of these females, but the households do not borrow against the weight of males (which is likely to result in productivity losses) or the nutritional status of children (which would likely result in reduced adult stature). There is suggestive evidence that excess variation in female BMI is achieved, at least in part, through food consumption which is marginally more volatile in the recursive group of households relative to other households (p-value=0.07). We conclude that households exploit all opportunities to improve the well-being of household members and, by revealed preference, households in the recursive group absorb the welfare costs of greater cycling in female weight in order to benefit from the welfare gains associated with behaving as if markets are complete. Measuring those welfare gains and identifying other, related behaviors remains a challenge for future research.

## 6. Conclusion

A new consumption-side test of the assumption that farm households behave as if production and consumption decisions are recursive has been developed and implemented using standard consumer budget data augmented with local market prices of farm inputs. Intuitively, under the assumptions of the recursive model, farm households treat all prices as parametric and so production choices on the farm will not depend on farm household characteristics or preferences of household members. Farm household decisions can be treated as if consumption choices are made after all production choices have been resolved even though the decisions are made simultaneously and updated over time. In that case, prices of inputs into the production process that are not consumed themselves will only have an income effect on consumer demand through a profit effect. This yields a weak separability result that places restrictions on the impact of those farm input prices on consumer demand: the ratios of the effects for any pair of farm inputs should be the same for all goods. In effect, failure to reject the recursion restriction implies that the assumption that households behave as if they face a complete set of markets is not rejected by the data.

The restriction is tested using longitudinal survey data collected from farm households in rural Central Java, Indonesia. For all households in the study area, the restriction is rejected indicating that production and consumption decisions cannot be treated as recursive. However, for the third of farm households with relatively more land, the restriction is not rejected indicating those households have developed mechanisms whereby their production and consumption choices can be treated as if markets are complete. We establish that one mechanism these household adopt to complete markets in the face of price and income innovations involves borrowing against their own human capital.

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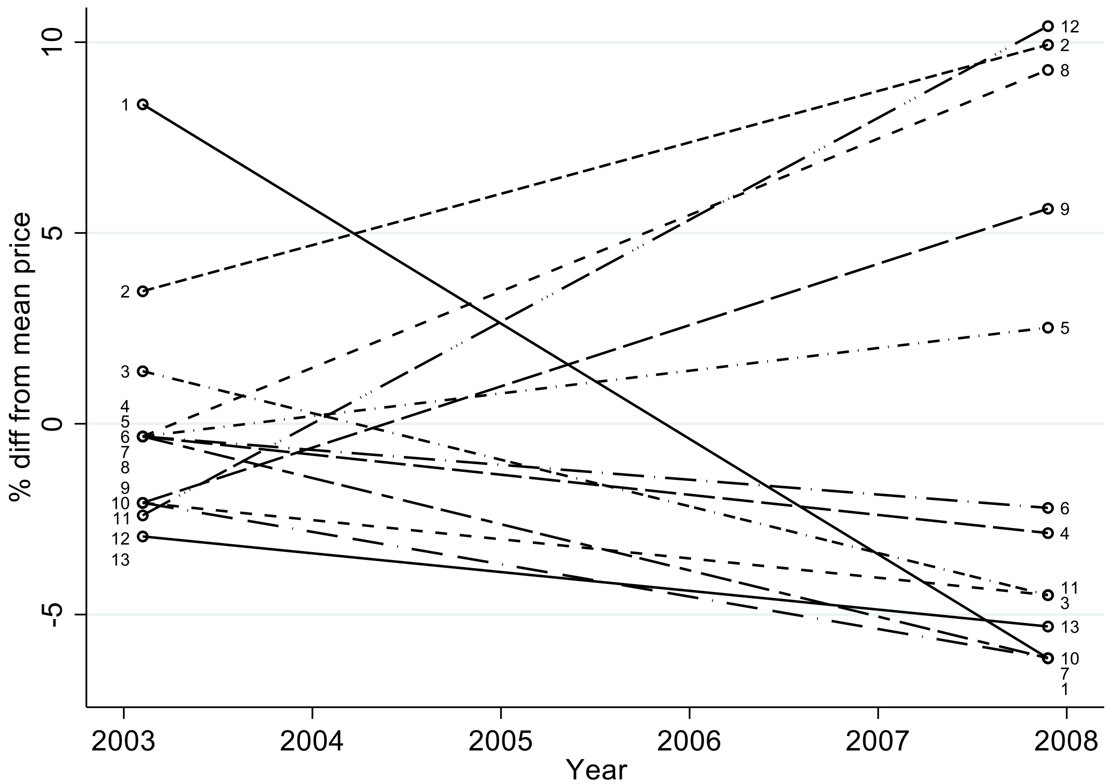
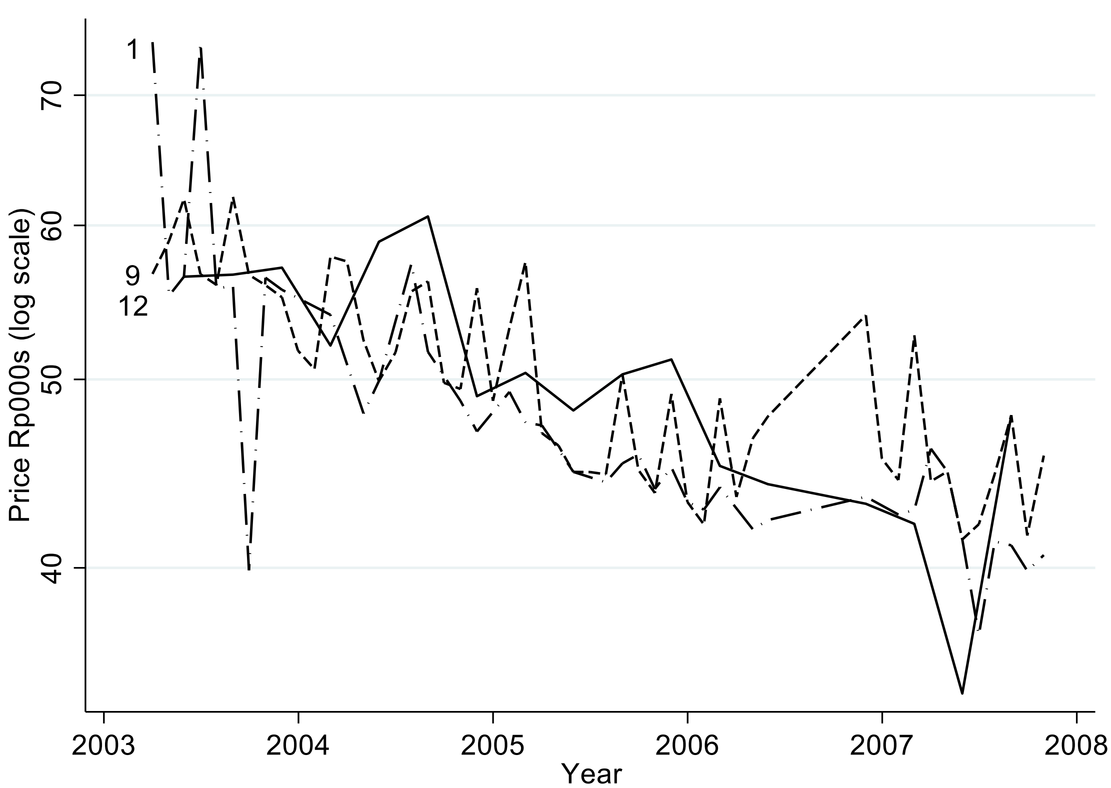
Figure 1. Fertilizer prices: Heterogeneity across markets over time

A. Summarizing price heterogeneity across markets at start and end of study
% deviation in fertilizer prices from average for study area in each market at each time point




B. Variation in real fertilizer prices in three markets during study period



# Table 1
## Descriptive Statistics

| *Household Characteristics* | (1) Mean (se) | *ln(Community Prices in Rp)* | (2) Mean (se) |
|---|---|---|---|
| *Share of Expenditure on […] (%)* | | *Price of […]* | |
| Grains | 16.66 | Grains | 7.69 |
| | (0.05) | | (0.0005) |
| Other foods | 43.66 | Other foods | 8.85 |
| | (0.07) | | (0.0002) |
| Goods for the home | 19.68 | Goods for the home | 9.79 |
| | (0.05) | | (0.0006) |
| Human capital related | 20.00 | Human capital related | 7.75 |
| | (0.08) | | (0.0005) |
| Per Capita Expenditure | 203.71 | *Input Prices* | |
| (Rp000/mo) | (0.95) | Rice seed | 9.62 |
| *Years of Education of […]* | | | (0.0005) |
| Primary Male | 5.59 | | |
| | (0.02) | Kangkung Seed | 9.89 |
| Primary Female | 5.09 | (water spinach) | (0.0011) |
| | (0.02) | | |
| *Age of […]* | | Insecticide | 10.86 |
| Primary Male | 54.54 | | (0.0007) |
| | (0.08) | | |
| Primary Female | 49.41 | Fertilizer | 10.57 |
| | (0.07) | | (0.0007) |
| Household Size | 3.76 | | |
| | (0.01) | | |
| Urban (%) | 13.42 | | |
| | (0.20) | | |
| Rainy Season (%) | 47.49 | N. Waves | 8 |
| | (0.29) | N. Households | 3825 |
| | | N. Observations | 29101 |

Notes: Table reports means and standard errors for variables of interest over the first waves of WISE used in the demand system estimation. Column 1 reports household level characteristics and column 2 community level prices. The sample consists of households with farm businesses. Per capita expenditure is in real Rp000/mo and all prices in log real Rp with January 2002 as the base (approximately 1USD). See appendix tables 1 and 2 for detailed information on the consumption goods used in creation of the composite expenditure shares and prices.

## Table 2
### Demand System Estimates

| | *Share of household expenditure (in %age terms) on [...]* | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | **Grains** | **Other foods** | **Goods for the home** | **Human-capital related** |
| *A. ln(consumption price indices)* | | | | |
| Grains | 2.12** | -1.05 | -0.42 | -0.64 |
| | (0.84) | (1.22) | (0.64) | (1.15) |
| Other foods | -0.18 | 2.01 | 0.37 | -2.19 |
| | (1.57) | (2.28) | (1.20) | (2.15) |
| Goods for the home | -1.36* | 2.51** | -0.34 | -0.81 |
| | (0.78) | (1.13) | (0.60) | (1.07) |
| Human-capital related | 1.91** | 0.30 | 1.33** | -3.53*** |
| | (0.77) | (1.12) | (0.59) | (1.06) |
| *B. Ln(PCE) linear splines* | | | | |
| 0-25th %ile | 2.28*** | 11.39*** | -14.97*** | 1.30** |
| | (0.39) | (0.56) | (0.30) | (0.53) |
| 25th-50th %ile | -4.11*** | 11.32*** | -11.55*** | 4.34*** |
| | (0.57) | (0.82) | (0.43) | (0.78) |
| 50th-75th %ile | -3.27*** | 7.35*** | -11.38*** | 7.30*** |
| | (0.51) | (0.74) | (0.39) | (0.70) |
| 75th-100th %ile | -0.92*** | 2.05*** | -8.84*** | 7.71*** |
| | (0.25) | (0.36) | (0.19) | (0.34) |
| *C. ln(prices of farm inputs)* | | | | |
| Fertilizer | 2.27*** | 0.93 | 0.31 | -3.52*** |
| | (0.70) | (1.02) | (0.54) | (0.96) |
| Rice seed | 0.74 | -4.45*** | 2.40*** | 1.30 |
| | (0.81) | (1.18) | (0.62) | (1.11) |
| Kangkung seed | -0.62** | 1.64*** | -0.66*** | -0.37 |
| | (0.29) | (0.42) | (0.22) | (0.40) |
| Insecticide | 0.02 | -0.98 | -1.16** | 2.12** |
| | (0.72) | (1.05) | (0.55) | (0.99) |
| *D. ln(wages)* | | | | |
| Female labor | 0.15 | 1.01 | 0.06 | -1.22* |
| | (0.51) | (0.74) | (0.39) | (0.69) |
| Male labor | 0.19 | -0.26 | -0.59 | 0.66 |
| | (0.49) | (0.71) | (0.37) | (0.67) |
| *E. Joint tests for farm input prices* | | | | |
| F statistic | 3.69 | 6.18 | 5.00 | 3.98 |
| *p*-value | 0.005 | 0.0001 | 0.001 | 0.003 |
| | | | | |
| Observations | 29101 | 29101 | 29101 | 29101 |
| N. of Households | 3825 | 3825 | 3825 | 3825 |

*Notes:* Robust standard errors that take into account clustering below coefficient estimates. Dependent variables are shares (in %ages) of household expenditure on the expenditure sub-aggregates in each column. All prices are in real terms. All models include household, community and time fixed effects. All models also include the log of the local female and male daily agricultural wage, education and and age of the primary male and female within the household, an indicators for whether or not the household is in an urban area, household composition, and indicators for the wave, year, and season. Standard errors appear below the point estimates and are calculated allowing for clustering at the household level.

*** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level

## Table 3
### Ratios of Price Effects and Tests of Equality

| | | *Share of Household Expenditure on [...]* | | | |
|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) |
| | | **Grain** | **Other foods** | **Goods for home** | **Human capital** |
| *A. ln(Price) Coefficient Ratios* | | | | | |
| Fertilizer to Rice Seed | | 3.06 | -0.21 | 0.13 | -2.70 |
| (std. error) | | (3.49) | (0.23) | (0.23) | (2.39) |
| | | | | | |
| *B. Pairwise ratio equality tests* | | | | | |
| Ratio relative to | Grain ratio | | -0.07** | 0.04** | -0.88 |
| | [p-val =1 ] | | [0.013] | [0.037] | [0.120] |
| | Other foods ratio | | | -0.62 | 12.86*** |
| | [p-val =1 ] | | | [0.241] | [0.006] |
| | Home goods ratio | | | | -20.77** |
| | [p-val =1 ] | | | | [0.012] |
| | | | | | |
| *C. Overall ratio equality tests* | | | | | |
| All six pairwise ratios equal [p-val] | | | | [.027]** | |

*** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level

## Table 4

**Non-linear Wald tests of equality of ratios of farm input price effects** (*p*-values)

| **Summary** | |
|---|---|
| Number of pairwise ratios | 36 |
| Number of rejections at 5% | 11 |
| Number of rejections at 10% | 15 |

| | | *p-values of tests of equality of ratios of price effects of* | | | | | |
|---|---|---|---|---|---|---|---|
| *Consumption sub-aggregates* | | | 1. Fertilizer to […] | | 2. Rice Seed to […] | | 3. Kangkung Seed to |
| *Budget share A* | *Budget share B* | Rice Seed | Kangkung Seed | Insecticide | Kangkung Seed | Insecticide | Insecticide |
| | | [1.1] | [1.2] | [1.3] | [2.1] | [2.2] | [3] |
| Grains | 1. Other foods | **0.013** | **0.007** | 0.438 | 0.389 | 0.846 | 0.648 |
| | 2. Goods for home | **0.037** | 0.126 | **0.093** | 0.338 | 0.684 | 0.339 |
| | 3. Human capital | 0.120 | **0.034** | 0.119 | 0.589 | 0.507 | 0.211 |
| Other foods | 4. Goods for home | 0.241 | 0.275 | 0.601 | 0.557 | **0.037** | **0.039** |
| | 5. Human capital | **0.006** | **0.005** | 0.660 | 0.814 | **0.064** | **0.062** |
| Goods for home | 6. Human capital | **0.012** | **0.037** | 0.130 | 0.991 | **0.044** | **0.069** |
| | 7. All price pairs | **0.027** | **0.034** | 0.264 | 0.818 | 0.188 | 0.190 |
| | 8. Overall - all price, good pairs | | 0.329 | | | | |

*Notes:* Table reports p-values from pairwise and joint tests of the ratio restrictions implied by separation in the agricultural household model. Each value represents the test for the pair of input prices in the column and consumption goods in the row. The final column tests equivalence across all pairs of price ratios for the goods in the corresponding row (6 restrictions). The overall joint test examines equality of all ratios reported in Table 3. Tests rejected at a 90% confidence level or above are highlighted in bold.

## Table 5

**Separation Ratio Test Results - Sample Stratified by Household Land Holdings** ($p$-values)

*A: Summary*

| | Household Land Holdings Relative to Community Mean: **Below** | **Above** |
|---|---|---|
| N. of Pairwise Ratios | 36 | 36 |
| N. of Rejections at 5% | 7 | 0 |
| N. of Rejections at 10% | 14 | 1 |

*B: Households with land holdings below their community mean*

| *Consumption sub-aggregates* | | *Ratio Test Results* | 1. Fertilizer to […] | | 2. Rice Seed to […] | | 3. Kangkung Seed to |
|---|---|---|---|---|---|---|---|
| *Budget share A* | *Budget share B* | Rice Seed | Kangkung Seed | Insecticide | Kangkung Seed | Insecticide | Insecticide |
| | | [1.1] | [1.2] | [1.3] | [2.1] | [2.2] | [3] |
| Grains | 1. Other foods | **0.022** | **0.021** | 0.353 | 0.890 | 0.252 | 0.265 |
| | 2. Goods for home | 0.117 | 0.181 | 0.263 | 0.910 | 0.987 | 0.932 |
| | 3. Human capital | **0.093** | **0.059** | 0.149 | 0.745 | 0.145 | 0.166 |
| Other foods | 4. Goods for home | 0.691 | 0.618 | 0.543 | 0.684 | **0.082** | **0.096** |
| | 5. Human capital | **0.032** | **0.021** | 0.322 | 0.673 | **0.040** | **0.044** |
| Goods for home | 6. Human capital | **0.055** | **0.095** | 0.582 | 0.644 | **0.046** | **0.064** |
| | 7. All price pairs | 0.115 | 0.112 | 0.498 | 0.975 | 0.204 | 0.224 |
| | 8. Overall | 0.565 | | | | | |

*C: Households with land holdings above their community mean*

| *Consumption sub-aggregates* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Budget share A* | *Budget share B* | | | | | | |
| Grains | 1. Other foods | 0.187 | 0.353 | 0.895 | 0.691 | 0.110 | 0.298 |
| | 2. Goods for home | 0.163 | 0.615 | 0.410 | 0.184 | 0.550 | 0.588 |
| | 3. Human capital | 0.650 | 0.465 | 0.578 | 0.607 | 0.178 | 0.188 |
| Other foods | 4. Goods for home | 0.700 | 0.298 | 0.208 | 0.281 | 0.379 | 0.234 |
| | 5. Human capital | 0.400 | 0.902 | 0.389 | 0.676 | **0.082** | 0.802 |
| Goods for home | 6. Human capital | 0.504 | 0.508 | 0.170 | 0.971 | 0.286 | 0.237 |
| | 7. All price pairs | 0.595 | 0.363 | 0.500 | 0.525 | 0.766 | 0.589 |
| | 8. Overall | 0.944 | | | | | |

*Notes:* Table reports $p$-values from pairwise and joint tests of the ratio restrictions implied by separation in the agricultural household model after stratifying the sample based on land holdings. Results for those households who own less than the within community mean appear in Panel B ($n$=19711). Results for those households with greater than the witin community mean appear in Panel C ($n$=9390). Each value represents the test for the pair of input prices in the column and consumption goods in the row. The final column tests equivalence across all pairs of price ratios for the goods in the corresponding row (6 restrictions). Demand system results for the stratified groups are available in Appendix Table A.6. Tests rejected at a 90% confidence level or above are highlighted in bold.

## Appendix Table A.1

### Expenditure sub-aggregates and budget shares

| Sub-aggregate | Budget Share (%) | Groups of goods (in survey) | Budget Share (%) | Detail |
|---|---|---|---|---|
| Staple grains | 16.66 | Rice | 12.48 | Hulled, uncooked |
| | | Other staples | 1.59 | Corn, sago/flour, cassava, tapioca, dried cassava, sweet potatoes, potatoes, yams |
| | | Dried foods | 2.59 | Noodles, rice noodles, uncooked noodles, macaroni, shrimp chips, other chips |
| Other foods | 43.66 | Meat and fish | 4.58 | Beef, mutton, goat, chicken, duck, salted meat and canned meat, fresh fish, salted fish, smoked fish |
| | | Vegetables | 3.77 | Kangkung, cucumber, spinach, mustard greens, tomatoes, cabbage, katuk, green beans, string beans and the like, beans like mung-beans, peanuts, soya-beans |
| | | Fruits | 2.84 | Papaya, mango, banana and the like |
| | | Tofu, tempe | 3.94 | |
| | | Milk, eggs, other dairy | 3.22 | Eggs, fresh milk, canned milk, powdered milk, cheese |
| | | Sugar | 4.27 | Javanese (brown) sugar, granulated sugar |
| | | Oil | 3.47 | Coconut oil, peanut oil, corn oil, palm oil |
| | | Spices | 3.10 | Sweet and salty soy sauce, salt, shrimp paste, chili sauce, tomato sauce, shallot, garlic, chili, candle nuts, coriander |
| | | Beverages | 1.59 | Drinking water, coffee, tea, cocoa, soft drinks (Fanta, Sprite, etc.), alcoholic beverages (beer, wine, etc.) |
| | | Tobacco products | 5.21 | Cigarettes, tobacco, betel nut |
| | | Prepared food | 7.67 | Food prepared out of the home |
| Goods for the home | 19.68 | Utilities and transportation | 6.32 | Electricity, water, fuel, transportation, including bus fare, cab fare, vehicle repair costs, gasoline |
| | | Household items | 2.21 | Laundry soap, cleaning supplies, personal toiletries, domestic servants |
| | | Household equipment and repair | 0.35 | Tables, chairs, kitchen tools, bed sheets, towels, repairs |
| | | Housing costs | 10.80 | Rent paid or rent that would be paid if home was rented |
| Human capital related goods | 20.00 | Education | 6.05 | Fees, tuition, books, school supplies, transport, meals and housing expenses |
| | | Health costs | 2.24 | Hospitalization costs, clinic charges, physician's fee, traditional healer's fee, medicines |
| | | Clothing (for adults & children) | 2.40 | Shoes, hats, shirts, pants, clothing for children |
| | | Ritual Ceremonies, Charities, Gifts | 6.69 | Weddings, circumcisions, tithe, charities, gifts |
| | | Recreation | 2.62 | Arisans, lotteries, outings, sport equipment |

*Notes:* Table provides a guide to the disaggregated goods in the WISE consumption module that are included in each of the composite goods used in the demand system estimation.

## Appendix Table A.2
### Composite Price Sources and Weights

| Price aggregate | Individual item | Source of price data | Weight in price index |
|---|---|---|---|
| **Grain** | Cassava | Pasar | 0.01 |
| | Cassavachip | Pasar | 0.07 |
| | Cassava leaves | Pasar | 0.02 |
| | Corn | Pasar | 0.03 |
| | Flour | Toko/Warung | 0.09 |
| | Noodle | Toko/Warung | 0.17 |
| | Potato | Pasar | 0.16 |
| | Rice | Toko/Warung | 0.41 |
| | Sweet Cassava | Pasar | 0.04 |
| **Other Food** | Apple | Pasar | 0.04 |
| | Beef | Pasar | 0.09 |
| | Cabbage | Pasar | 0.01 |
| | Carrot | Pasar | 0.01 |
| | Chicken | Pasar | 0.04 |
| | Chili | Toko/Warung | 0.01 |
| | Cigarettes | Toko/Warung | 0.14 |
| | Coconut | Pasar | 0.002 |
| | Coffee | Toko/Warung | 0.01 |
| | Cucumber | Pasar | 0.01 |
| | Eggs | Toko/Warung | 0.02 |
| | Garlic | Toko/Warung | 0.01 |
| | Green Bean | Pasar | 0.01 |
| | Kangkung | Pasar | 0.01 |
| | Lima Bean | Pasar | 0.01 |
| | Milk Powder | Pasar | 0.12 |
| | Mineral Water | Pasar | 0.07 |
| | Mujair | Pasar | 0.03 |
| | Nuts | Pasar | 0.01 |
| | Oil | Toko/Warung | 0.02 |
| | Onions | Toko/Warung | 0.01 |
| | Oranges | Pasar | 0.04 |
| | Papaya | Pasar | 0.0002 |
| | Pindang | Pasar | 0.03 |
| | Salak | Pasar | 0.02 |
| | Salt | Toko/Warung | 0.003 |
| | Spinach | Pasar | 0.005 |
| | Sugar | Toko/Warung | 0.02 |
| | Sweet Milk | Toko/Warung | 0.07 |
| | Tea | Toko/Warung | 0.01 |
| | Tempe | Toko/Warung | 0.02 |
| | Teri | Pasar | 0.01 |
| | Tobacco | Pasar | 0.03 |
| | Tofu | Pasar | 0.02 |
| | Tomato | Pasar | 0.01 |
| | Tongkol | Pasar | 0.04 |
| **Home Goods** | Detergent | Toko/Warung | 0.09 |
| | Gas (LPG) | Pasar | 0.50 |
| | Kerosene | Toko/Warung | 0.19 |
| | Soap | Toko/Warung | 0.22 |
| **Human Capital** | Cotton | Pasar | 0.02 |
| | Dress | Pasar | 0.02 |
| | Notebook | Toko/Warung | 0.90 |
| | Pants | Pasar | 0.02 |
| | Slippers | Toko/Warung | 0.03 |

*Notes:* Table summarizes the individual prices that are utilized in constructing composite prices. Weights are determined using the 2002 SUSENAS detailed expenditure survey for households in Purworejo kabupaten.

## Appendix Table A.3
### Demand Systems for Stratified Samples

| | Farm household land holdings that are less than the community mean<br>*Share of Household Expenditure on […]* | | | | Farm household land holdings that are greater than the community mean<br>*Share of Household Expenditure on […]* | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | **Grains** | **Other foods** | **Goods for the home** | **Human capital** | **Grains** | **Other foods** | **Goods for the home** | **Human capital** |
| *A. ln(consumption price indices)* | | | | | | | | |
| Grains | 2.14** | -1.30 | -0.20 | -0.64 | 2.02 | -0.91 | -0.79 | -0.31 |
| | (1.06) | (1.48) | (0.76) | (1.35) | (1.34) | (2.16) | (1.19) | (2.16) |
| Other foods | -0.50 | 3.65 | -0.54 | -2.61 | 0.59 | -1.59 | 2.54 | -1.55 |
| | (1.98) | (2.75) | (1.42) | (2.52) | (2.50) | (4.05) | (2.23) | (4.04) |
| Goods for the home | -0.34 | 2.21 | -0.34 | -1.53 | -3.32*** | 2.68 | -0.25 | 0.89 |
| | (0.99) | (1.37) | (0.71) | (1.26) | (1.24) | (2.00) | (1.10) | (2.00) |
| Human capital related | 3.23*** | 0.25 | 0.67 | -4.15*** | -0.85 | 0.54 | 2.86*** | -2.55 |
| | (0.97) | (1.35) | (0.70) | (1.24) | (1.24) | (2.02) | (1.11) | (2.01) |
| *B. Ln(PCE) linear splines* | | | | | | | | |
| 0-25th Percentile | 2.29*** | 11.46*** | -15.10*** | 1.35** | 2.02*** | 11.00*** | -14.58*** | 1.56 |
| | (0.45) | (0.63) | (0.32) | (0.57) | (0.77) | (1.25) | (0.69) | (1.25) |
| 25th-50th Percentile | -3.37*** | 11.33*** | -11.64*** | 3.68*** | -5.91*** | 11.29*** | -11.25*** | 5.87*** |
| | (0.70) | (0.97) | (0.50) | (0.89) | (0.97) | (1.57) | (0.86) | (1.56) |
| 50th-75th Percentile | -2.71*** | 7.95*** | -12.08*** | 6.84*** | -4.54*** | 5.92*** | -9.97*** | 8.59*** |
| | (0.66) | (0.91) | (0.47) | (0.83) | (0.79) | (1.28) | (0.70) | (1.28) |
| 75th-100th Percentile | -0.09 | 2.70*** | -8.94*** | 6.33*** | -1.89*** | 1.29** | -8.74*** | 9.34*** |
| | (0.34) | (0.48) | (0.25) | (0.44) | (0.34) | (0.55) | (0.30) | (0.54) |
| *C. ln(prices of farm inputs)* | | | | | | | | |
| Rice Seed | 1.75* | -5.23*** | 2.32*** | 1.16 | -1.22 | -2.89 | 2.45** | 1.65 |
| | (1.02) | (1.42) | (0.73) | (1.30) | (1.31) | (2.11) | (1.17) | (2.11) |
| Kangkung Seed | -0.57 | 1.89*** | -0.67** | -0.66 | -0.81* | 1.04 | -0.56 | 0.33 |
| | (0.37) | (0.51) | (0.26) | (0.47) | (0.47) | (0.76) | (0.42) | (0.75) |
| Insecticide | 2.69*** | -0.47 | 0.50 | -2.72** | 1.20 | 3.69** | -0.12 | -4.77*** |
| | (0.88) | (1.22) | (0.63) | (1.12) | (1.13) | (1.83) | (1.01) | (1.83) |
| Fertilizer | -0.74 | -1.07 | -1.00 | 2.81** | 1.68 | -0.97 | -1.46 | 0.76 |
| | (0.91) | (1.26) | (0.65) | (1.15) | (1.18) | (1.91) | (1.05) | (1.90) |
| *D. ln(wages)* | | | | | | | | |
| Female labor | -0.40 | -0.11 | -0.04 | 0.56 | 1.17 | 3.12** | 0.33 | -4.62*** |
| | (0.64) | (0.89) | (0.46) | (0.82) | (0.80) | (1.30) | (0.72) | (1.30) |
| Male labor | 0.31 | -0.42 | -0.68 | 0.78 | 0.07 | 0.04 | -0.40 | 0.29 |
| | (0.62) | (0.85) | (0.44) | (0.78) | (0.78) | (1.26) | (0.70) | (1.26) |
| *E. Joint tests for farm input prices* | | | | | | | | |
| F statistic | 3.464 | 6.265 | 4.179 | 2.962 | 2.228 | 1.871 | 1.894 | 1.917 |
| *p*-value | 0.008 | 0.00005 | 0.002 | 0.02 | 0.063 | 0.112 | 0.109 | 0.105 |
| Observations | 19,711 | 19,711 | 19,711 | 19,711 | 9,390 | 9,390 | 9,390 | 9,390 |

*Notes:* Table reports demand system estimates similiar to those in Table 2, but for stratified sample. Households are divided by their landholdings relative to the within community mean. Outcomes are shares of household expenditure on the composite good in each column, and all prices are expressed in real terms as the log of 2002 Rp0,000. Knots in the log PCE distribution are placed at the 25%, 50% and 75% percentile. Additional controls include the log of the local daily agricultural wage for men and women, the education and and age of the primary male and female within the household, an indicators for whether or not the household is in an urban area, household composition, and indicators for the wave, year, and season. Standard errors appear below the point estimates and are calculated allowing for clustering at the household level.

*** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level