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FARM PROFITS, PRICES AND HOUSEHOLD BEHAVIOR

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ABSTRACT

The agricultural 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 that 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 including, for example, links between health, nutrition and labor markets,[1] wage determination, labor supply and agricultural productivity shocks,[2] risk and human capital investments,[3] the allocation of resources among family members,[4] property rights,[5] technology adoption[6] and microcredit and financial markets.[7]

Key in this model is the assumption that farm-households make decisions as if markets are complete. This assumption underpins the powerful result that the simultaneous production and utility maximization problem can be modeled recursively with farm profit maximization occurring in a first stage without reference to consumption choices and, in the second stage, farm-households maximize utility treating profits from farm production as given (Singh, Squire and Strauss, 1986). The implication that production decisions can be analyzed independently of preferences underlies many of the existing empirical tests of the complete markets assumption. There are two classes of those 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.[8] 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.[9]

This paper develops and implements a novel test drawing on the second implication of the complete markets assumption: consumption choices of farm-households can be investigated without taking into account how resources are allocated in the farm business. This consumption-side test, which is a complement to production-side tests, is straightforward to implement using standard survey data on household expenditures in conjunction with data on prices. It does not require data

[1] Strauss (1982, 1984) and Thomas et al. (2016).
[2] Rosenzweig (1980), Kochar (1999), Carter and Yao (2002), Jayachandran (2006), Barrett et al. (2008), Dillon and Barrett (2017), Kaur (2019), Breza et al. (2021), Gollin and Udry (2021), and Shamdasani (2021).
[3] Jacoby and Skoufias (1997).
[4] Udry (1996), Duflo and Udry (2004), Rangel and Thomas (2019) and Edmonds and Theoharides (2020).
[5] Field (2007).
[6] Barnum and Squire (1979), de Janvry, Fafchamps and Sadoulet (1991), Conley and Udry (2010), Suri (2011) and Jones et al. (2022).
[7] Kaboski and Townsend (2011), Beaman et al. (2023) and Bau and Matray (2023).
[8] See, for example, Udry (1999), Bowlus and Sicular (2003), LaFave and Thomas (2016), Dillon and Barrett (2017) and Dillon et al. (2019) for applications.
[9] Jacoby (1993), Lambert and Magnac (1998), Carter and Yao (2002) and Barrett et al. (2008).

on farm production.

Whereas the earliest production-side tests failed to reject recursion, recent evidence using the same tests indicates that the assumption is rejected. However, empirical implementation of those tests is not straightforward. Studies have had to confront substantial measurement challenges, and tests based on the estimation of production functions also make strong assumptions about unobserved heterogeneity.

While it is unlikely that low-income, rural settings are characterized by a complete system of markets, a good deal of evidence has established that farm-households organize their economic and social lives in ways that provide the resources necessary to make the best choices for themselves and their families, adapting their behaviors to take into account missing markets (Barnum and Squire, 1979). For example, studies have established that in some contexts families and communities share risk by providing insurance and resources in times of need, even in the face of large, unanticipated shocks. In these contexts, families are able to smooth seasonal variation in income and make choices that mitigate liquidity constraints.[10] 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.[11]

This paper makes three contributions. First, we develop a consumption-side test that exploits the fact that, under recursive two-stage budgeting, factors that affect only farm business profits in the first stage are restricted to only have an income effect on consumption choices in the second stage. 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 using standard consumption data in conjunction with data on market-level prices of farm inputs. The tests can be implemented in settings where it is possible to measure local area market

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[10] Rosenzweig (1988), Rosenzweig and Stark (1989), Paxson (1992, 1993), Rosenzweig and Wolpin, (1993), Townsend (1994), Zimmerman and Carter (2003), Frankenberg et al (2003), Stillman and Thomas (2008), Frankenberg et al. (2018) Lawton et al. (2024), Lombardo et al., (2024).

[11] Chandrasekhar, Kinnan and Larreguy, (2018), Thomas et al. (2004), Banerjee et al. (2024).

prices for at least some farm inputs. We also show that these consumption-side tests are not subject to specification and estimation concerns that arise with production-side tests.

Third, 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 and 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. The utility function in every period is assumed to satisfy the standard axioms of completeness, transitivity, reflexivity, monotonicity, strict convexity and continuity. 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:

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

$$E^L_{it} = L^F_{it} + L^O_{it} + \ell_{it} \qquad [3]$$

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

where β_t is the discount rate, x_{mt} is a vector of market consumption goods, x_{ct} is consumption of agricultural goods (i.e. food, some of which may be grown by the household), and ℓ_t is a vector of household members' leisure. Preferences are captured by μ_t and ε_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 ν_{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^L_{it}, is allocated between working in the family business, L^F_{it}, outside the family business, L^O_{it} and leisure, ℓ_{it}. Total household time is the sum of these endowments over all members, i=1...N, $E^L_t = \sum_i E^L_{it}$. 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, $p_{ct} x_{ct}$. It is worth underscoring that, in the model, all prices of all inputs and outputs are the market-clearing prices faced by the farmer. The farmer does not need to participate in those markets but, under the recursion assumption, the farmer chooses allocations taking into account the shadow values of each input and output as indicated by their price in the local area market.

Solving [1] through [4], demand for market, x_{mt}, and home–produced goods, x_{ct}, depends on all prices of market goods, p_{mt}, output prices of home produced goods, p_{ct}, input prices in the production function that are variable, p_{vt}, and those that are fixed, p_{At}, the shadow value of time of each household member, w_{it}, and the overall price index, $\bar{P}_t$, as well as non-labor income, y_t, (or income from wealth, $r_t W_t$), given observed household characteristics, μ_t, such as demographic composition and unobserved characteristics, ε_t, such as preferences:

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

where market and home produced goods are collected together and denoted x_g. Under the assumption of additive inter-temporal separability, past prices and expectations about future prices only affect current demand through the impact on the marginal utility of income which is absorbed in μ_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].[12] Conditional on these allocations, the household

[12] 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.

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.

2.2 Consumption-side tests for recursion

In each period of the recursive model, farm-households maximize profits, π_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:

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

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 compared 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, π_t^*, as given:

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

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:

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

The key insight is that, under the recursion 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. 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_{v_1} and p_{v_2}, that affect demand only through the profit function, the ratio of their effects on demand is

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

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:

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

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.

It is useful to note that, by Hotelling's Lemma, the effect of price on profits is input demand, $\frac{\partial \pi^*}{\partial p_{v_1}} = V_1$ in the case of input 1, and so that the ratio in the center of [12] is the ratio of the demand for the inputs, 1 and 2:

$$\frac{\frac{\partial x_{g_j}}{\partial p_{v_1}}}{\frac{\partial x_{g_j}}{\partial p_{v_2}}} = \frac{V_1}{V_2} = \frac{\frac{\partial x_{g_k}}{\partial p_{v_1}}}{\frac{\partial x_{g_k}}{\partial p_{v_2}}} \qquad \forall\ j, k \in G \qquad [13]$$

precisely because these inputs do not enter the utility function directly, but their prices affect demand only through their influence on profits. As shown in [9], the test is predicated on the assumption that neither input has a direct effect on consumption which rules out tests based on inputs in production that are also consumed and requires that an overall price index be included in the model to assure that identification is based on variation in relative prices.

This formulation highlights a second important point: if inputs into the production function are constrained for any reason, [13] will not be valid, in general, and recursion will be rejected. This applies not only to inputs used in the tests but all inputs into production: in general, any deviation from profit maximization will result in failure of recursion. There are two potential caveats. First, if the effect of inputs V_1 and V_2 on profits are orthogonal to the effect of all other inputs, [13] will hold: in general, this is very unlikely to be the case and, specifically, is not likely to be relevant in the context of our tests as we use prices of seeds, fertilizer, and insecticide.

A second caveat arises if the model can be re-specified in terms of a conditional profit function that is optimized given a long-term constraint such as an input that is fixed over the long-term. The canonical example of such an input is land used for production (which, of course, is not the same as land owned). To the extent that farmers optimize input choices given these constraints on inputs, the tests can be interpreted as providing evidence on recursion conditional on those fixed factors. This points to an advantage of using panel data that spans multiple seasons or years.

Liquidity constraints and lack of access to credit has played a central role of many studies of consumer behavior. The assumption in [8] that welfare is inter-temporally separable assures that resources can be transferred across time at the appropriate discount rate and thus recursion will be rejected if the consumer-producer faces restrictions such as lack of access to credit or insurance. Notice that while inter-temporal separability is important, no restrictions are placed on the shape of the utility function other than the usual regularity conditions.

Consumption-based tests of whether farm-household decisions are recursive avoid many of the empirical challenges that complicate estimation and interpretation of production-side tests. There are two main classes of production-side tests: those that rely on estimation of production or profit functions and those that rely on estimation of input demand functions.

The latter tests sidestep many of the difficulties encountered in the empirical estimation of production functions which are notoriously difficult to estimate for several reasons. These include, for example, specifying complex production functions where the productivity of complementary inputs is potentially linked to the timing and sequencing of inputs; the need to measure the quantity and quality of every input; and the need to treat input choices as endogenous; and, therefore, construct a credible instrument for each input. As an example, it is a challenge to measure the quality of land, a key input into agricultural production. Widely-cited studies have drawn incorrect conclusions about the efficiency of resource allocation because of unobserved variation in plot fertility in spite of conducting extensive assessments of soil quality and topography. (See, for example, Udry, 1996, and follow-up work by Goldstein and Udry, 2008.) Some of the difficulties in measurement of labor inputs are discussed below. Estimation of multi-product production functions raises additional challenges which need to be addressed in the not uncommon situations when farms produce multiple crops and allocation of inputs to specific crops is not straightforward.

Input demand functions have provided some of the most compelling tests of recursion in the literature. These functions are not straightforward to estimate not only because of complementarity of inputs and the key role of timing of the application of inputs, as noted above, but also because measurement of inputs can be complicated. Consider, as an example, measurement of (effective) labor input on a farm when multiple family members work on the farm at varying times through the year with some potentially multitasking. The effective units of labor are unlikely to be homogenous, although few studies attempt to take heterogeneity in productivity into account in the measurement of labor inputs. Furthermore, recalling labor input over a season or a year adds further complications since time allocation is seldom smooth over the period and the extent of lumpiness typically varies with task and type of worker. There are few examples of large-scale studies that have collected contemporaneous data on inputs at each stage of production. Taking into account the quality or efficiency of the labor is difficult, and the problem is compounded if a farmer supervises other family members or non-family workers. These problems are likely to be greater for data collected from larger farms which complicates comparisons of behavior of farmers across the distribution of farm sizes. Further, in our Indonesian context, many farmers provide labor for short periods of time on a neighbor's farm during critical periods in the production cycle in return for labor on their own farm; accurately measuring this type of short-term exchange labor input in a survey is difficult. To be concrete, the rejection of recursion in the seminal study by Benjamin (1992) is explained by systematic understatement of own labor and labor of other family and non-family members supplied to the farm (LaFave and Thomas, 2016).

On the other hand, consumption-side tests can be implemented using standard consumption survey data that are routinely collected in many studies as long as consumption and market-level prices of inputs into farm production are also available. (These prices might be collected as part of the survey or obtained from external sources.) It is imperative that prices are measured well and there is sufficient independent variation in the market prices of farm inputs across space and/or over time, conditional on variation in an overall price index and consumption prices. It is also imperative that prices are plausibly exogenous from the perspective of the farmer; this is a reasonable assumption for market-level prices in the case of individual small-scale farmers who do not wield market power. This requirement rules out the use of unit prices of goods that are purchased by farmers as they likely reflect both quality variation and quantity discounts which are likely related to farm and farmer characteristics (McKelvey, 2011). For this study, we collected prices for a set of goods and services in standardized units and, where applicable, for specific brands that we had determined were widely available based on pre-testing. This ensured that the prices were comparable across space and time and reflected the prices farmers actually faced if they were to purchase an additional unit of the input. Conceptually, each input price is intended to represent the shadow price of the marginal unit of that input in farm production. It is possible that the input prices we have collected are measured with error in which case the tests for recursion may be contaminated. We take this up in the empirical analyses below and document that our conclusions are robust to allowing substantial measurement error.

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 from [9], we estimate an extension of the Almost Ideal Demand System (Deaton and Muellbauer, 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, ω_{ghmt}, depends on the logarithm of per capita household 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, $p_{\gamma mt}$ ($\gamma=1,\ldots G$), wages, w_{mt}, (which is also vector-valued and measured at the local market m level for different types of labor), and a market-level, time-varying price index, $\overline{P}_{mt}$. 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.[13] 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:

$$\omega_{ghmt} = f_g(\ln PCE_{ht}) + \ln p_{\gamma mt}\beta_{g\gamma} + \ln w_{mt}\beta_{gw} + \ln \overline{P}_{mt}\beta_{gm} + \ln p_{vmt}\beta_{gv} + z_{ht}\beta_{gh} + \lambda_{hm} + \varepsilon_t + \varepsilon_{ghmt} \qquad [14]$$

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

[13] 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.

include a farm-household fixed effect, λ_{hm}, which can be interpreted as a proxy for permanent income so that the effects of ln(PCE) 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 deviations between local market prices and the prices paid by the household arising because of quality differences or quantity discounts, for example, and thus assures that the estimates are not contaminated by farm-household-specific variation in prices paid by the farmer. The fixed effects also absorb 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 include a market-level monthly price index, P_{mt}, so that all estimated effects of prices of goods, *g*, farm inputs, *v*, and wages, *w*, are interpreted relative to changes in the overall local-market price index over time. The model also includes time effects, ε_t, to take into account aggregate price changes due to seasons or shocks that affect the entire study area. Time-varying, good-specific heterogeneity in tastes of households is captured in ε_{ghmt}.

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

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

for each pair of goods, *j* and *k*, in *G* and for each pair of input prices, *y* and *z*, in *V*.[14] 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: [15]

$$\beta_{g_j v_y} * \beta_{g_k v_z} = \beta_{g_k v_y} * \beta_{g_j v_z} \qquad \forall\ j, k \in G,\ \ y, z \in V \qquad [16]$$

[14] As is apparent from the theory, the estimated effects of farm input prices in [14] are not informative about whether decision-making is recursive on their own. If decisions are not recursive, there are no restrictions placed on the price effects in [14].

[15] Note also that if the price of an input is measured with random noise, the estimated price effects will be attenuated. The noise to signal ratio will appear on both sides of the Wald test statistic in the product form [16] and thus not bias the test. This is not the case in the ratio form [15]: the downward biased estimates of the price effects in the denominator have the potential to cause substantial error in testing based on that form. This is a practical example of the advantage of the cross-product formulation of the test.

It is important to note that [16] should hold for each pair of goods and pair of farm inputs. Failure of [16] 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 *kabupaten* located along the coast of Central Java, Indonesia (Thomas et al., 2016). Conducted in conjunction with a randomized iron supplement intervention, WISE is a large-scale population-representative longitudinal survey of farm-households, communities and local markets that was conducted between 2002 and 2007. About 90% 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, and small and large livestock.

There are active labor and product markets in the area, making it an appropriate setting for the empirical application. Ninety percent of farm-households hire in labor, 78% have at least one household member who works off the farm in a non-family business, and only 2% have neither hired-in labor nor those working off-farm. 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. Ninety-six percent of households report selling agricultural output at some point during the course of the study.

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 144 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.[16]

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 takes into account unobserved factors that are fixed over time and affect consumer demand in a linear way. This includes time-invariant factors that affect market prices as well as farm input and technology choices, such as farmer and farm quality. It is imperative that the benefits of the longitudinal design are not offset by attrition during the eight 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 225 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,[17] the survey collects information about spending over the previous week as well as the value of consumption of food produced on the farm or provided in kind. Parallel information, including the value of home produced goods, 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.[18] The recall period for each consumption item is based on extensive experience collecting consumption data in Indonesia and

[16] None of the conclusions about recursion are affected by exclusion of the 2007 wave.
[17] 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.
[18] 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.

balances the 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, the estimation of demand systems with zero expenditures is a substantial challenge and aggregation sidesteps 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 and fourteen sub-aggregates are noted 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 of the 144 study communities, 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 area. This included the collection of detailed information on prices of goods and services. The enumerators visited *warungs* (local stalls), *tokos* (shops), and *pasars* (markets) 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. 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, enumerators who lived in the area collected transaction prices for specific, standardized consumption items. For each item, the size or quantity and, where applicable, the brand was prespecified 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. The stores that served a particular community were visited each month 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 our market-level, monthly price index. While this index closely tracks an aggregated regional price index based on prices in cities that is available from Statistics Indonesia, it also takes into account market-specific price variation. 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 A2 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, 89% of farms report expenditure on seeds and 99% purchase fertilizer and insecticides. Farmers who do not purchase seed are likely to be storing seed from their previous crop; the opportunity cost of that seed is the price of replacing it in the event that it cannot be used, which is the market price of seed. 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 may move together over time, even after taking into account inflation; this covariation is taken into account in the empirical model [14] by the inclusion of the market-specific price index and aggregate 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 and the overall market price index, it is possible to empirically test whether variation in the relative prices of farm inputs is explained by variation in consumption prices. Appendix Table A3 reports these results. For example, in a model relating the ln(price) of rice seed to the ln(price) of each of the four consumption goods, displayed in column 1, none of the effects of consumption prices is substantively large or statistically significant; taken together the consumption prices are not statistically significant as shown by the p-value of 0.387 for the F test for joint significance in the penultimate row of the table. If there is insufficient independent variation in farm input prices given consumption prices, it is most likely to be evident for the prices of rice seeds and grains. As shown in the table, this is not a concern in these data: the coefficient on the price of grains is 0.03 (with a standard error of 0.085). The same patterns describe the relationships between the prices of the other three farm inputs and consumption goods. We conclude there is no evidence that relative farm input prices are significantly correlated with relative consumption prices.

It is helpful to provide information on the sources of variation in farm input prices that are exploited in the empirical models. Figure 1 displays fertilizer prices over time, which we have aggregated from the market level that is used in the models to the *kecamatan* level for illustrative purposes. Panel A of the figure summarizes changes in prices in each *kecamatan* over the entire study period. The percentage deviation of the price in each *kecamatan*, relative to the average fertilizer price in the study area at the beginning of the study (in 2003) is displayed in the left hand column and at the end of the study (in late 2007) in the right hand column. Each line represents a *kecamatan* and the rank order of each *kecamatan* (from highest baseline price to lowest baseline price) is indicated by the number next to the endpoint of each line. The heterogeneity across *kecamatan* 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 *kecamatan* with the highest price at baseline has the lowest price at the end of the study; the *kecamatan* 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 *kecamatan* during the study period as illustrated in panel B of the figure which displays fertilizer prices for three of the *kecamatan*. (The figure is difficult to read with more *kecamatan*.) There is considerable month-to-month variation in prices which reflects variation in supply and demand in each *kecamatan* 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 the demand system, [14], 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 [14] 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, $p_{\gamma t}$, 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.[19] 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 and survey wave fixed effects. Standard errors reported below the estimates are robust to heteroscedasticity and take into account clustering at the market-wave level.

The own-price estimates for shares of human-capital related goods and goods for the home are negative and statistically significant. In contrast, the own-price effects for the shares of grains and other foods are positive and statistically significant. 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 ln(PCE) 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 finding alone is not informative about recursion as it is consistent with input prices having a direct effect on demand, an indirect effect through profits or both the direct and indirect effects.

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 [15]. To illustrate this test, ratios for the first pair of input prices,

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[19] Results are robust to alternative shapes of the ln(PCE) function. Knots at the 25th percentiles closely match non-parametric estimates of the relationships between budget shares and ln(PCE) using locally weighted smoothed scatterplots and a 5% bandwidth.

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 (2.92 in panel C of Table 2) to the effect of rice seed prices (0.14) on grain demand is reported in the first column (20.86) along with its standard error. The corresponding ratios for demand for other food, goods for the home, and human capital are -0.45, -0.05, and -4.20.

These ratios should be the same if farm-household production and consumption decisions are recursive. Equivalently, rewriting [15], 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 using fertilizer and rice seed prices. 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, -0.45 to 20.86, is equal to -0.02 and we reject the null of one with a p-value of 0.037, thus rejecting the predictions of recursion. Across all pairs, the test statistics clearly deviate from the null of one and range from -0.20 to 90.49. Four of the six tests are rejected at the 5% level. Panel C of Table 3 reports the overall test of equality across all six pairwise ratios which is rejected as well (p-value = 0.072).

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 [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 tests to be rejected and, with a 10% size of test, 4 of the tests will be rejected. In fact, 12 of the 36 tests (or 33%) are rejected at a 5% size of test and 13 (or 36%) 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.[20, 21]

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[20] 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.

[21] Results from larger demand systems including finer disaggregation of goods are consistent with the four-good illustration reported here. A 7 good system with 126 pairwise tests results in 24 rejections at 10% and 14 goods (546 pairwise tests) 72 rejections.

5.3 Robustness of results

It is imperative that the estimates of the effects of prices of farm inputs are not contaminated because of misspecification of the demand system. First, it is important to fully control for income effects and we noted that our spline function mimics flexible nonparametric estimates. Estimates of price effects and their standard errors are essentially identical if the spline in ln(PCE) is, instead, specified with knots at every 5th percentile. For example, in the specification with knots at 25th percentiles reported in Table 2, the effect of fertilizer prices on the grain budget share is 2.92 (standard error=0.75) and the effect of insecticide prices is -0.23 (standard error=0.74). With knots at every 5th percentile, the estimates and (standard errors) are 2.97 (0.75) and -0.25 (0.74), respectively.

Second, we have documented that there is independent variation in farm input prices and consumption prices, after taking into account variation in a market-level time-varying price index. To check that the estimates are not affected by unobserved market-level time-varying factors, we included a market-level time trend in the demand system [14]. It is not a significant predictor of consumption shares and the number of rejections of separation were little impacted. Without the time trend we have 13 and 12 rejections at 10 and 5% sizes of tests, respectively; with the time trend there are 14 and 9 rejections, respectively.

Measurement error is an important concern in studies using household survey data. While we worked hard to measure prices accurately in the field, we cannot rule out the possibility that measurement error contaminates our results. We have explored the robustness of our results along this dimension by simulating how they change when random noise is added to the input prices. With 100 simulations, for a 10% size of test, we have 13 rejections with no noise, the same number with 10% random noise and 12 rejections with 20% random noise. Even with 50% random noise, we have 7 rejections. We draw two conclusions. Measurement error would bias us away from the rejections that we do find, and that it would require substantial error to push the tests toward failing to reject. It seems very unlikely that our results can be explained by measurement error.

5.4 Do any farm-households behave 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 other connections that are a potential source of insurance or risk sharing. Land is the primary asset in Purworejo and so to explore this hypothesis we stratify households based on land holdings at baseline and contrast those who have more than the average land holdings for households in their community with those households who have less than average land holdings.[22] The two groups of households are compared in Appendix Table A4. Since the distribution of land holdings is skewed to the right, about two-thirds of all households are in the smaller farm group, and the difference in average land holdings across the two groups is very large. Relative to smaller farm-households, larger farm-households have over twice the assets, 25% higher per capita expenditure, they spend a smaller fraction of their budget on food, particularly staples, and more on human capital related goods. While household size is very similar, larger farm-households have older and better educated household heads.

Table 5 reports the same set of non-linear Wald tests as in Table 4 for the 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 community. Panel C includes those households that have more than the average land holdings. The corresponding demand system estimates are reported in Appendix Table A5.

For the poorest two-thirds of farm-households in panel B, 8 of the 36 pairs of ratios (or 22%) are significantly different from each other at a 5% size of test and 14 of the pairs of ratios (39%) 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 5% or 10% test sizes. 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.[23]

This is an important result for two reasons. First, we have identified a group of households

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[22] This is similar in spirit to studies using production side tests to assess sub-sample heterogeneity in market completeness (e.g. Dillon and Barrett, 2017; Dillon et al., 2019; and Kebede, 2022). Carter and Yao (2002), for example, use a sample of 397 households to examine village-level heterogeneity in recursion linked to land-transfer regulations across five counties in China. Here we assess heterogenous behavior across households within the same communities.

[23] We conducted simulations to assess the power of the tests in the absence of heterogeneity in market completeness for subsamples of the same size as the smaller and larger farm groups. At a 10% size of test, we would expect 7 rejections for smaller farms and 3 rejections for larger farms, compared to the observed 14 and 0 indicating the tests are not underpowered. If the groups of households are stratified into subsamples with the same number of households (i.e. at the median of farm size), there are a small number of pairwise rejections for larger farms and about twice as many for smaller farms. This likely reflects misclassification of farmers in the middle of the farm size distribution that do not make choices as if there are complete markets.

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 failed to reject recursion for sub-groups of the farm-households.

Over and above identifying households that behave as if markets are complete, the consumption-side 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 examine one dimension of observed behavior: borrowing against human capital of household members, specifically adult weight and child height. We chose 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 to protect the nutritional status of young children in their families (Thomas and Frankenberg, 2006; Frankenberg and Thomas, 2018).

We compare variation during the study period in BMI of female adults in households in the recursive group 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 survey wave 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.[24] 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, the 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 (perhaps due to potential 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

We develop and implement a new consumption-side test of the assumption that farm-households behave as if production and consumption decisions are recursive 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

[24] Female adults in the recursive group have slightly higher mean BMIs at baseline, 21.93, compared to others, 21.67 (p-value = 0.03).

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 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 households adopt to complete markets in the face of price and income innovations involves borrowing against their own human capital.

The consumption-side test relies on consumption data that are routinely collected in multi-purpose farm and household surveys along with market-level prices of inputs used in production. If market-level price data are not collected as part of the survey, it may be possible to use administrative data on local area prices. A strength of the test is that it is not necessary for all farmers to buy inputs in the market but only that prices for inputs can be measured at the local area market level. If some farmers in a community do not buy inputs in the market but rely on own production of inputs and do not value those inputs at the market price in their decision-making, the recursion assumption will be rejected for those farmers. They may co-exist with farmers in the same area for whom the recursion assumption is not rejected, some of whom may buy inputs in the market while others may not but they behave as if shadow prices of inputs are equal to the local area market prices. Of course, in contexts where markets for farm inputs do not exist, consumption-side tests for separation will not be informative. In those contexts, it seems unlikely that farm households behave as if markets are complete.

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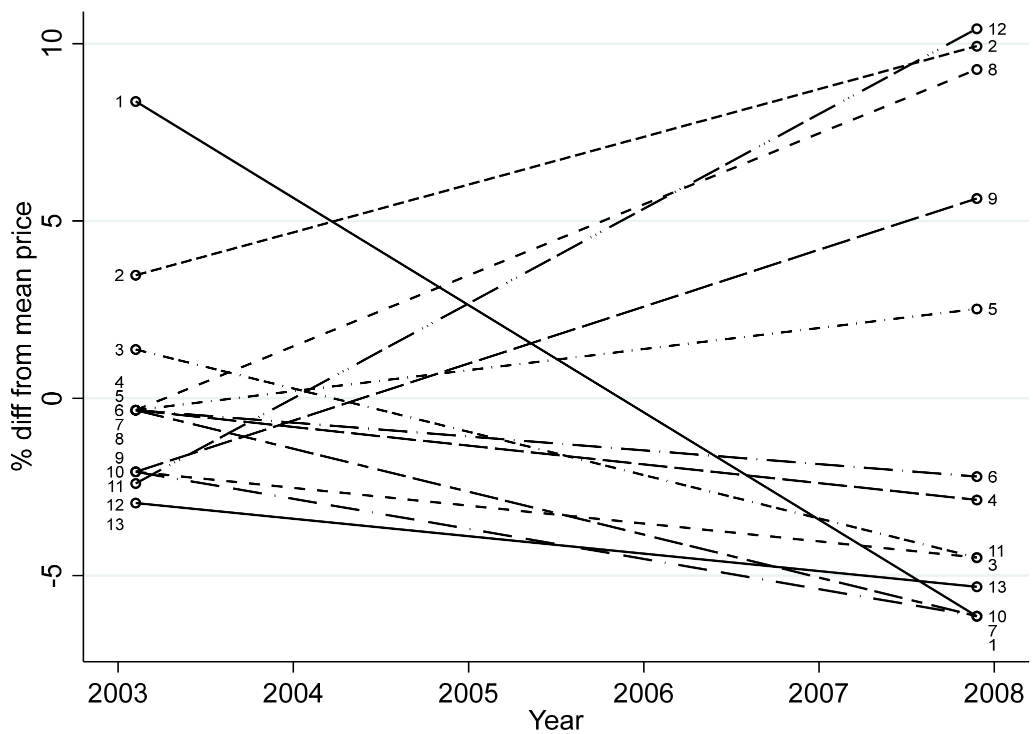
Figure 1. Fertilizer prices: Heterogeneity across markets over time

A. Summarizing price heterogeneity across *kecamatan* at start and end of study
Percent deviation in fertilizer prices from average for study area in each market at each time point.
Numbers next to each line denote the *kecamatan's* rank order based on price deviation at the baseline.



B. Variation in real fertilizer prices in three *kecamatan* during the study period

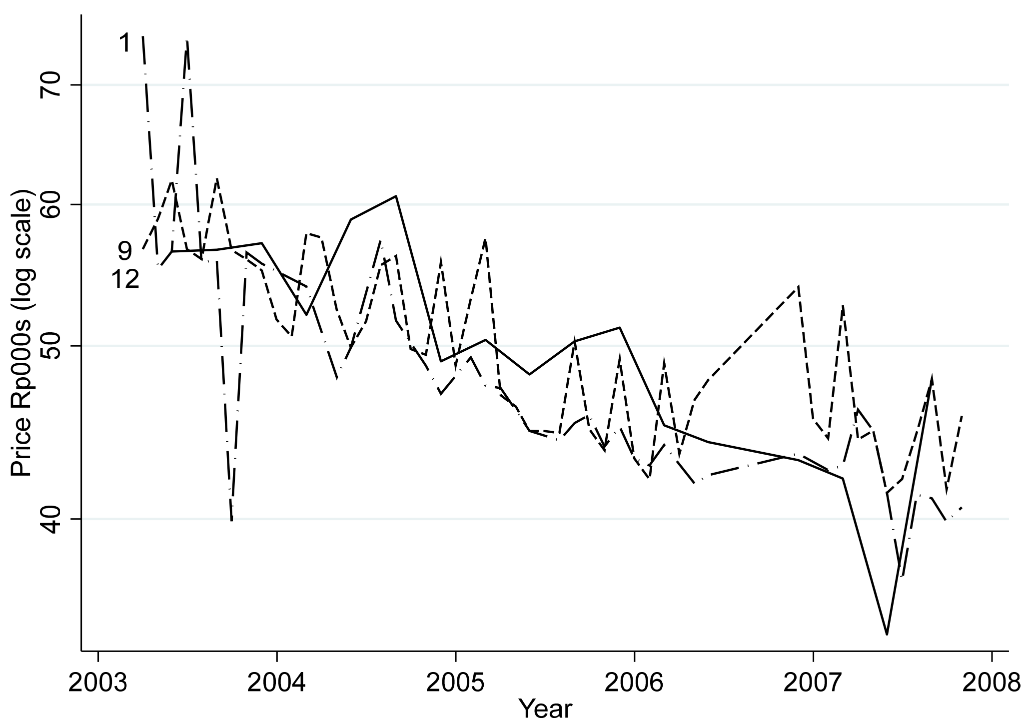


Table 1
Descriptive Statistics

Household Characteristics	(1) Mean (se)	*ln(Community Prices in Rp)*	(2) Mean (se)
Share of Expenditure on […] (%)		*Price of […]*	
Grains	16.66	Grains	7.79
	(0.05)		(0.0005)
Other foods	43.66	Other foods	8.95
	(0.07)		(0.0002)
Goods for the home	19.68	Goods for the home	9.89
	(0.05)		(0.0006)
Human capital related	20.00	Human capital related	7.85
	(0.08)		(0.0005)
Per Capita Expenditure	227.12	*Input Prices*	
(Rp000/mo)	(1.06)	Rice seed	9.72
Years of Education of […]			(0.0005)
Primary Male	5.59		
	(0.02)	Kangkung Seed	9.99
Primary Female	5.09	(water spinach)	(0.0011)
	(0.02)		
Age of […]		Insecticide	10.68
Primary Male	54.54		(0.0007)
	(0.08)		
Primary Female	49.41	Fertilizer	10.96
	(0.07)		(0.0007)
Household Size	3.76		
	(0.01)	N. Waves	8
Urban (%)	13.42	N. Households	3825
	(0.20)	N. Observations	29101
		N. Markets	144

Notes: Table reports means and standard errors for variables of interest. 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. 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	2.93***	-0.78	-0.36	-1.79
	(0.83)	(1.22)	(0.59)	(1.13)
Other foods	-1.06	5.20**	-1.94	-2.21
	(1.74)	(2.51)	(1.32)	(2.43)
Goods for the home	-0.46	2.98**	-1.11*	-1.41
	(0.81)	(1.26)	(0.63)	(1.18)
Human-capital related	2.54***	0.43	0.83	-3.80***
	(0.86)	(1.26)	(0.60)	(1.13)
B. Ln(PCE) linear splines				
0-25th %ile	1.92***	11.22***	-14.91***	1.77***
	(0.51)	(0.55)	(0.30)	(0.48)
25th-50th %ile	-3.19***	9.81***	-11.42***	4.80***
	(0.59)	(0.75)	(0.38)	(0.72)
50th-75th %ile	-3.03***	7.22***	-11.37***	7.17***
	(0.52)	(0.81)	(0.39)	(0.78)
75th-100th %ile	-1.30***	2.73***	-8.83***	7.41***
	(0.29)	(0.57)	(0.25)	(0.67)
C. ln(prices of farm inputs)				
Fertilizer	2.92***	1.40	-0.09	-4.24***
	(0.75)	(1.07)	(0.53)	(0.97)
Rice seed	0.14	-3.09**	1.94***	1.01
	(0.83)	(1.17)	(0.67)	(1.12)
Kangkung seed	-0.25	1.54***	-0.68***	-0.61
	(0.30)	(0.46)	(0.24)	(0.41)
Insecticide	-0.23	-0.21	-1.48***	1.92*
	(0.74)	(1.07)	(0.56)	(0.99)
D. ln(wages)				
Female labor	0.07	1.19	-0.12	-1.15
	(0.49)	(0.79)	(0.36)	(0.72)
Male labor	0.04	-0.30	-0.50	0.76
	(0.49)	(0.79)	(0.36)	(0.72)
E. Joint tests for farm input prices				
F statistic	4.26	4.84	5.74	5.88
p-value	0.002	0.001	0.0001	0.0001
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 models include household and time fixed effects. All models also include the log of the monthly local price index, the local female and male daily agricultural wage, education and and age of the primary male and female within the household, an indicator for whether or not the household is in an urban area, and household composition. *** 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		20.86	-0.45	-0.05	-4.20
(std. error)		(127.26)	(0.39)	(0.28)	(4.66)
B. Pairwise ratio equality tests					
Ratio relative to	Grain ratio		-0.02	-0.002	-0.20
	[p-val =1]		[0.037]**	[0.018]**	[0.444]
	Other foods ratio			0.10	9.27
	[p-val =1]			[0.362]	[0.036]**
	Home goods ratio				90.49
	[p-val =1]				[0.016]**
C. Overall ratio equality tests					
All six pairwise ratios equal [p-val]				[.072]*	

** 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%	12
Number of rejections at 10%	13

Consumption sub-aggregates		*p-values of tests of equality of ratios of price effects of*					
		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	**0.037**	**0.007**	0.930	0.698	0.745	0.724
	2. Goods for home	**0.018**	**0.019**	**0.028**	0.611	0.898	0.744
	3. Human capital	0.444	0.108	0.255	0.789	0.776	0.440
Other foods	4. Goods for home	0.364	0.473	0.233	0.571	0.106	**0.044**
	5. Human capital	**0.036**	**0.019**	0.679	0.877	0.117	0.105
Goods for home	6. Human capital	**0.016**	**0.029**	**0.019**	0.667	**0.064**	**0.039**
	7. All price pairs	**0.072**	**0.031**	0.233	0.991	0.405	0.265
	8. Overall - all price, good pairs		0.189				

Notes: Table reports p-values from pairwise and joint tests of the 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 overall joint test examines all 36 price, good pairs. Tests rejected at a 90% confidence level or above are highlighted in bold.

Table 5

Separation 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%	8	0
N. of Rejections at 10%	14	0

B: Households with land holdings below their community mean

Ratio Test Results

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	**0.023**	**0.011**	0.730	0.704	0.304	0.306
	2. Goods for home	**0.042**	**0.047**	**0.077**	0.826	0.781	0.648
	3. Human capital	0.227	**0.082**	0.258	0.585	0.302	0.315
Other foods	4. Goods for home	0.891	0.878	0.990	0.662	0.132	**0.097**
	5. Human capital	**0.043**	**0.032**	0.754	0.549	**0.085**	0.102
Goods for home	6. Human capital	**0.046**	**0.084**	0.125	0.441	**0.055**	**0.035**
	7. All price pairs	0.107	**0.091**	0.501	0.984	0.340	0.288
	8. Overall	0.515					

C: Households with land holdings above their community mean

Consumption sub-aggregates							
Budget share A	*Budget share B*						
Grains	1. Other foods	0.733	0.214	0.470	0.328	0.664	0.483
	2. Goods for home	0.458	0.268	0.460	0.249	0.980	0.257
	3. Human capital	0.528	0.464	0.316	0.890	0.629	0.770
Other foods	4. Goods for home	0.264	0.415	0.174	0.730	0.623	0.437
	5. Human capital	0.739	0.315	0.811	0.613	0.794	0.819
Goods for home	6. Human capital	0.212	0.239	0.144	0.629	0.619	0.997
	7. All price pairs	0.866	0.732	0.735	0.897	0.995	0.899
	8. Overall	0.965					

Notes: Table reports p-values from pairwise and joint tests of the 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. Demand system results for the stratified groups are available in the appendix. 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

Relationship between Input and Consumption Prices

	Ln price of [...]			
	(1)	(2)	(3)	(4)
	Rice Seed	**Fertilizer**	**Kangkung Seed**	**Insecticide**
ln(consumption price indices)				
Grains	0.030	-0.012	0.045	-0.111
	(0.085)	(0.060)	(0.158)	(0.101)
Other foods	0.108	-0.308	-0.418	0.176
	(0.189)	(0.183)	(0.229)	(0.194)
Goods for the home	0.089	0.005	-0.130	-0.100
	(0.062)	(0.076)	(0.194)	(0.055)
Human-capital related	-0.087	-0.076	0.180	-0.015
	(0.064)	(0.059)	(0.139)	(0.062)
Joint significance (p-value)	0.387	0.102	0.086	0.414
Observations	1,152	1,152	1,152	1,152

Notes: Robust standard errors that take into account clustering below coefficient estimates. Dependent variables are ln(prices) of farm inputs measured at the market-survey wave level. All models include market and wave fixed effects and flexibly control the overall market-time specific log price index.

Appendix Table A.4
Differences Across Small and Large Farms

	Households with land holdings [...]	
	Below Community-Mean	Above Community-Mean
	(1)	(2)
Farm land owned (m2)	682.96	4985.30
	(7.27)	(275.19)
Household Assets (Rp0,000)	2163.40	4928.80
	(19.84)	(66.32)
Per Capita Expenditure	209.69	263.70
(Rp000/mo)	(1.15)	(2.17)
Share of Expenditure on [...] (%)		
Grains	17.17	15.58
	(0.06)	(0.08)
Other foods	43.88	43.22
	(0.09)	(0.13)
Goods for the home	19.66	19.74
	(0.06)	(0.08)
Human capital related	19.29	21.46
	(0.09)	(0.14)
Household Size	3.73	3.82
	(0.01)	(0.02)
Age of [...]		
Primary Male	53.27	57.22
	(0.09)	(0.13)
Primary Female	48.31	51.73
	(0.09)	(0.13)
Years of Education of [...]		
Primary Male	5.31	6.20
	(0.03)	(0.05)
Primary Female	4.87	5.55
	(0.03)	(0.04)
Observations	19711	9390

Notes: Table reports means and standard errors for variables of interest between small and large farms.

Appendix Table A.5
Demand Systems for Stratified Samples

	Farm household land holdings that are less than the community mean				Farm household land holdings that are greater than the community mean			
	Share of Household Expenditure on […]				*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	2.69**	-0.69	-0.29	-1.72	3.37***	-1.34	-0.48	-1.55
	(1.07)	(1.47)	(0.72)	(1.30)	(1.30)	(2.07)	(1.13)	(2.06)
Other foods	-1.74	7.23**	-2.75*	-2.73	0.10	1.04	0.14	-1.28
	(2.24)	(3.16)	(1.54)	(2.74)	(2.73)	(4.45)	(2.78)	(4.34)
Goods for the home	0.41	3.00*	-1.06	-2.36*	-2.18	2.47	-1.17	0.88
	(1.06)	(1.55)	(0.77)	(1.41)	(1.33)	(2.14)	(1.18)	(2.16)
Human capital related	3.87***	0.43	0.14	-4.44***	-0.23	0.51	2.41**	-2.69
	(1.08)	(1.44)	(0.83)	(1.27)	(1.36)	(2.07)	(1.18)	(2.19)
B. Ln(PCE) linear splines								
0-25th Percentile	1.96***	11.37***	-15.07***	1.75***	1.76*	10.53***	-14.44***	2.16**
	(0.61)	(0.63)	(0.36)	(0.52)	(1.06)	(1.17)	(0.58)	(1.04)
25th-50th Percentile	-2.56***	10.17***	-11.53***	3.93***	-4.85***	9.29***	-11.14***	6.70***
	(0.70)	(0.93)	(0.46)	(0.79)	(1.02)	(1.37)	(0.74)	(1.30)
50th-75th Percentile	-2.20***	7.22***	-12.16***	7.13***	-4.65***	6.75***	-9.85***	7.75***
	(0.65)	(0.96)	(0.49)	(0.89)	(0.77)	(1.36)	(0.68)	(1.38)
75th-100th Percentile	-0.72	3.78***	-8.86***	5.79***	-1.99***	1.42	-8.81***	9.38***
	(0.45)	(0.75)	(0.33)	(0.82)	(0.37)	(0.86)	(0.38)	(1.03)
C. ln(prices of farm inputs)								
Fertilizer	3.38***	0.02	0.11	-3.51***	1.77	4.07**	-0.55	-5.29***
	(0.91)	(1.28)	(0.61)	(1.14)	(1.21)	(1.79)	(1.04)	(1.87)
Rice seed	0.90	-3.90***	1.93***	1.07	-1.36	-1.60	1.98	0.99
	(1.04)	(1.39)	(0.75)	(1.26)	(1.40)	(2.12)	(1.31)	(2.12)
Kangkung seed	-0.20	1.84***	-0.68**	-0.95**	-0.42	0.88	-0.61	0.15
	(0.38)	(0.53)	(0.29)	(0.50)	(0.47)	(0.77)	(0.47)	(0.77)
Insecticide	-0.94	-0.42	-1.27*	2.63**	1.27	0.15	-1.92*	0.49
	(0.92)	(1.27)	(0.66)	(1.16)	(1.22)	(1.88)	(1.06)	(1.94)
D. ln(wages)								
Female labor	-0.47	-0.03	-0.20	0.69	1.09	3.49**	0.08	-4.66***
	(0.62)	(0.91)	(0.43)	(0.80)	(0.82)	(1.44)	(0.75)	(1.46)
Male labor	0.10	-0.44	-0.57	0.91	0.00	-0.02	-0.28	0.30
	(0.57)	(0.84)	(0.41)	(0.76)	(0.87)	(1.25)	(0.68)	(1.37)
E. Joint tests for farm input prices								
F statistic	3.68	4.58	3.69	4.05	1.67	1.92	2.01	2.23
p-value	0.006	0.001	0.005	0.003	0.156	0.104	0.091	0.064
Observations	19,711	19,711	19,711	19,711	9,390	9,390	9,390	9,390

Notes: Robust standard errors that take into account clustering below coefficient estimates. 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. *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level