Missing credit markets and commodity marketing behavior

Emma C. Stephens* and Christopher B. Barrett†

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*Corresponding Author and Ph.D. Candidate, Department of Economics, Cornell University, Ithaca, NY, 14853, ecs33@cornell.edu.

†Professor, Department of Applied Economics and Management, Cornell University, Ithaca, NY, 14853, cbb2@cornell.edu.

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Agricultural households in environments characterized by many market inefficiencies have a multitude of difficult decisions to make regarding the production and management of their agricultural produce. With high transactions costs to marketing and purchasing commodities, some households rationally self-select out of markets and choose to balance demand and supply internally out of household production. The consequences of this behavior have been extensively examined in the context of externally observed responses to different price or agricultural policy interventions, or the impact of demand or supply inelasticity in the missing market on the non-missing markets in which the household participates (de Janvry, Fafchamps & Sadoulet 1991; Omamo 1998; Key, Sadoulet & de Janvry 2000).

In order to make the decision to participate in a given market for goods that the household both produces and consumes, the household must compare the market price of the good, net of any transactions costs, with an internal shadow value that represents the implicit ‘market clearing’ price for the commodity. Thus the shadow price represents the value at which internal demand and supply equilibrate for non-tradable goods. The decision making framework that incorporates possible self-selection out of markets and the role of the shadow price was substantially developed by de Janvry, Fafchamps and Sadoulet (1991). Borrowing from the literature on international trade, they adapt the concept of the non-tradables price band (a range of prices for which trade between countries is no longer profitable) to the agricultural household model and examine the household level marketing behavior in the presence of household specific transactions costs. They demonstrate that the existence of transactions costs can lead to a similar “non-tradables price band” around a given market price for a commodity produced by the
household. As a consequence, the household will rationally self-select out of the market, as long as the household’s internal shadow price for the commodity is within this price band.

Several important studies have subsequently examined observed market participation behavior using the agricultural household model with transactions costs developed by de Janvry et. al. by analyzing the correlates of the household’s market participation decision. Goetz (1992) studied coarse grain supply sales and purchase decisions for households in Senegal by evaluating a two-stage participation model. In the first stage, participation as a buyer or seller is modeled as a binary (0,1) choice and is assumed to be a function of market prices, household characteristics and proxies for positive transactions costs. Then, selection correction terms from the first stage participation decision are calculated and used along with a subset of the correlates from the first stage to examine the actual purchase and sale quantities transacted by household who are market participants. This study reveals several important features of market response, including the differences between unconditional and conditional (upon market participation) supply elasticities that certainly impact any policy analysis of market interventions and farmer welfare. The first stage estimation also corrects the second stage analysis by accounting for the presence of autarkic farmers and the almost certain selection issues present in studying only market participants.

Key, Sadoulet and de Janvry (2000) directly estimate a supply response curve for corn producers in Mexico and show the different impact of fixed and proportional transactions costs on farmer supply response by demonstrating a supply discontinuity that is attributable to the presence of fixed costs incurred when farmers use the market. An
increase in fixed costs will increase the size of the discontinuity between buyer and seller marketed transaction quantities. Bellemare and Barrett (2006) introduce an ordered tobit estimator of market participation to analyze the timing of the entry and quantity transacted decisions in Kenyan and Ethiopian livestock markets. Others have also looked at technology adoption and cropping choices in the presence of positive transactions costs (Moser and Barrett, forthcoming; Omamo, 1998).

Most of the above studies rely on cross-sectional data on observed market purchase and supply behavior to estimate the approximate supply response of farmers to prices and make inferences about the importance of various transactions costs. However, this supposes that the observed supply response is representative of a constant, underlying market supply curve that can be used to make these estimations. But, the observed supply curve is a function of the position of the underlying shadow price for the commodity, which is in turn a function of the household’s balance of internal supply and demand for the commodity in question. If, between harvests, the household is thought of as trying to maintain a competitive storage equilibrium, at least internally, for any good that is not traded on the market; e.g. (Williams and Wright 1991), then between harvests, the shadow price that clears internal demand and supply can change if available stocks of the commodity are gradually being used during the interharvest period, which is a reasonable assumption based on a household’s gradual auto consumption of their own agricultural output in the period between harvests. As well, due to the non-separable nature of consumption and production decisions when markets are not complete, as is the case for many agricultural communities, changes in consumption demand for tradable goods may also affect the demand and supply for non-tradables, which then affects the
shadow price. Therefore the possibility emerges when analyzing the interharvest period that a household’s internal shadow price for non-tradable goods may be changing over time. If this is the case, then the observed supply response curves must also be changing over time. Therefore, previous studies that analyze supply response at a more aggregated time step may not capture this behavior and in particular may not adequately explain the phenomenon of the same household selling agricultural output for low prices with subsequent purchases later at higher prices.

In this article we combine the literature on market participation with that of consumption smoothing (Zeldes 1989; Deaton 1991), to develop an adapted agricultural household model that can explain the impact of missing credit markets on farmer external supply response over time that partly explains the ‘sell low’/‘buy high’ phenomenon. We argue that a reduced ability to smooth consumption due to the presence of a liquidity constraint affects the household’s shadow price for non-tradable goods due to the non-separable nature of production and consumption decisions with positive market transactions costs. Further, a credit constrained household’s shadow price for any non-tradable output should exhibit a higher variance between harvests than the equivalent shadow price for non-constrained households. The supply response curves for credit-constrained farmers should thus be distinct from the supply curves of non-credit constrained farmers. As well, the supply response curves in the period immediately following a harvest should lie below the supply response curves later on in the interharvest period (lean season), with credit constrained households having a larger spread between the harvest and lean seasons. These concepts are examined using a two-stage market participation approach that controls for prospective selection bias.
Model development

Our model of the agricultural household’s dynamic market participation decisions depends upon four principal features that result in the household’s per period optimal demand, supply, and storage decisions and therefore to their ultimate observed behavior: consumption smoothing, liquidity constraints, marketing regime choice and seasonal price patterns.

Consumption smoothing and liquidity constraints

One possible way to think about farmer marketing decision making over time is to look at their ability to smooth consumption and the implications for marketing and market participation. Households are assumed to try and equate the marginal utility of consumption of both traded and non-traded goods across time periods in order to obtain maximum lifetime utility. However, in the presence of liquidity constraints, the key, intertemporal mechanism for achieving this maximum is missing for the household as they cannot borrow in times of low income to smooth consumption. Therefore, households may not be able to spread consumption over time optimally.

A simplified version of the household’s intertemporal maximization problem (over a generalized utility function $U(\bullet)$ with household specific tastes and capabilities, $\theta$) in the face of such liquidity constraints is given in equation (1). Assume that the household only consumes a non-marketed commodity in each time period $t$, $c_t$, as well as a marketed commodity, $x_t$. In each period the household produces a tradable crop, $q_t$, and a non-tradable crop, $q_{c,t}$, and has the ability to save cash ($S_t$) or keep the non-traded good in storage each period (represented by $ST_t$). Also assume that an additional liquidity constraint now applies each period such that $S_t, ST_t \geq 0$. The household uses its own
labor, \(L_{f1}\) and \(L_{f2}\) to produce the tradable output, \(q_t\), and non-tradable output \(q_{c,t}\) respectively. The household can also earn off-farm income at wage, \(w\), for labor \(L_{of}\) (total labor in the household is \(L_T = L_{f1} + L_{f2} + L_{of}\)). The price of the \(x_t\) is numeraire, while the price of the traded commodity that the household can sell can change each period and is given by \(p_{q,t}\). The household must choose consumption of the tradable and non-tradable good, as well as production output and next period’s cash savings and grain storage:

\[
\begin{align*}
\text{Max} & \quad E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, x_t; \theta) \\
\text{s.t.} & \quad (1) \quad x_t + S_t \leq p_{q,t} q_t + S_{t-1} + wL_{of} \quad \text{(cash budget constraint)} \\
& \quad c_t + ST_t \leq q_{c,t} + ST_{t-1} \quad \text{(non-tradables resource constraint)} \\
& \quad S_t \geq 0, ST_t \geq 0 \quad \text{(liquidity and non-negative storage constraint)}
\end{align*}
\]

The solution to problem (1) is a series of output supply, consumption demand and storage and savings equations that are functions of current and expected future prices as well as current and future realizations of full income, \(Y\) (which is evaluated as the value of the current period’s remaining non-traded output that either gets sold in the market or used for consumption of the non-tradable good)\(^1\):

\(^1\) This is a stylized version of how households manage their output and sales decisions between harvests and does not incorporate the dynamics of consumption due to a time lag between planting and production as in Behrman, Foster and Rosenzweig (1997). Agricultural production of the tradable good is assumed to provide a stream of income that can be used for tradables consumption each period.
\[
\begin{align*}
&x_{i,t} = x(p_{i,t}, E_t, p_{j,t+1}, p_{j,t}, E_t, p_{j,t+1}, Y_t, E_{i,t+1}), \\
&c_{i,t} = c(p_{i,t}, E_t, p_{j,t+1}, p_{j,t}, E_t, p_{j,t+1}, Y_t, E_{i,t+1}), \\
&S_t = S(p_{i,t}, E_t, p_{j,t+1}, p_{j,t}, E_t, p_{j,t+1}, Y_t, E_{i,t+1}), \\
&ST_t = ST(p_{i,t}, E_t, p_{j,t+1}, p_{j,t}, E_t, p_{j,t+1}, Y_t, E_{i,t+1}), \\
&q_{i,t} = q(p_{i,t}, E_t, p_{j,t+1}, p_{j,t}, E_t, p_{j,t+1}; \theta)
\end{align*}
\]

\(\forall i \in \text{Tradables}, \quad j \in \text{Non - Tradables}\)

In the case of a binding cash liquidity constraint, the household cannot equate the marginal utility of consumption of the good \(x\) over all periods, and optimally reduces current consumption and increase future consumption to compensate for the binding constraint. In this case the marginal utility of good \(x\) is higher in the early periods than would otherwise be the case if the household were able to borrow, as can be seen from the Euler equations representing the first order conditions for the choice of \(x_t\) (under binding liquidity constraint, \(\lambda_t\)) for problem (1):

\[(3) \quad U'_x(c_t, x_t; \theta) = E_0 \beta [U'_x(c_{t+1}, x_{t+1}; \theta) + \lambda_t] \Rightarrow U'_x(c_t, x_t; \theta) > E_0 \beta [U'_x(c_{t+1}, x_{t+1}; \theta)]
\]

As the resultant demand and supply equations that solve problem (1) contain both market and shadow prices, any changes in the consumption of the tradable good \(x_t\) that might be induced by the liquidity constraint as shown in (3) will also affect the household’s consumption of non-tradables and therefore the internal shadow price. To determine more specifically how the liquidity constraint affects the shadow price of the non-traded good, we can compute the elasticity of the shadow price of the non-traded good to the price of the consumption good purchased in the market, which has become relatively more expensive with respect to accumulating savings when the liquidity constraint binds. This elasticity can be shown to be a complex function of the different elasticities at work in the household’s decision making. For example, the elasticity of the
time $t$ shadow price of the non-traded commodity, $c$ (given by $p_j$) with respect to the contemporaneous market good price, $p_i$ is a function of the own and cross-price demand elasticities of $c$ with respect to current and expected future prices (these are the $\theta$ terms in equation (4) below), the income elasticity of the consumption good $c$ w.r.t. current and expected future income (the $\eta$ terms) and the output supply elasticities of non-traded good $q_j$ w.r.t. both the tradable and non-tradable current and future prices (the $E$ terms)$^2$:

\[(4)\]

\[
\text{Elasticity}_{pj,pj} = \frac{(\theta_{c,p_i} \gamma + \theta_{c,p_j} \gamma \eta_{c,Y} + \eta_{c,Y} \gamma \alpha_{i} + \eta_{c,Y} \gamma \alpha_j - E_{q,j} \cdot p_i - E_{q,j} \cdot p_j)}{(E_{q,j} \cdot p_j + E_{q,j} \cdot \pi_j \cdot \gamma - \theta_{c,p_j} \gamma - \theta_{c,p_j} \gamma \eta_{c,Y} + \theta_{c,p_j} \gamma \alpha_j - \eta_{c,Y} \gamma \mu_j - \eta_{c,Y} \gamma \nu_j - \eta_{c,Y} \gamma \nu_j)}
\]

Similar expressions can be derived for different combinations of current and future shadow prices and market prices, as well as external elasticities that indicate supply and demand response in the marketed goods to changes in the shadow price. As an aside, the elasticity above also depends upon the expected “responsiveness” or elasticity of future prices w.r.t. current prices (these are the $\Theta$ terms in equation (4)). If market and shadow prices are i.i.d. and the household does not engage in any storage of output, then the $\Theta$ terms disappear and the elasticity reduces to the following expression:

\[(5)\] “Independent Prices” Elasticity$_{pj,pj} = \frac{(\theta_{c,p_i} \gamma + \eta_{c,Y} \gamma \alpha_{i} + -E_{q,j} \cdot p_i)}{(E_{q,j} \cdot p_j - \theta_{c,p_j} \gamma - \eta_{c,Y} \gamma \alpha_j)}$

which is only dependent upon current prices and income and is essentially equivalent to the response elasticity originally calculated in de Janvry, Fafchamps and Sadoulet in their 1991 article. However, it seems unlikely that shadow prices for non-traded goods are

$^2$ Full derivation of this elasticity is provided in the appendix.
uncorrelated over time and it is this dependence that adds further complication to the prediction of the direction of shadow price response to changes in market prices. Thus, the actual sign of equation (4) is difficult to determine. But, never the less, credit constraints in the tradable sector do appear to affect consumption in the non-tradable sector due to the impact of changing tradable good consumption on the shadow price.

*Marketing regime choice and seasonality*

The household maximization problem defined in equation (1) models a household with a specific set of tradable and non-tradable goods over which utility is defined. However, the household in fact determines which goods are tradable and non-tradable in response to market prices. We follow a procedure similar to Key, Sadoulet and de Janvry (2000) for determination of the marketing regime by evaluating the maximization problem (1) under the different decision prices available to sellers, buyers and households who self-select out of markets. We then compare the indirect utility possible under these three regimes to determine regions over which a household will decide to participate in the market as a seller, buyer or will remain in autarky. This will result in the determination of the household’s overall supply response curve and we can then compare these curves between credit-constrained and non-credit constrained households.

In the base case of non-credit constrained households who face positive proportional transactions costs, (temporarily ignoring any fixed transactions costs for ease of exposition), the household supply response function to different market prices is essentially the same as in Key et. al. and is replicated in Figure 1. We assume that the following sequence of events occurs when the household makes its marketing regime choice:
1. The household evaluates the shadow price for a good that it produces and consumes as a non-tradable, (taking the marketing regimes of other goods as given) by determining the optimal consumption demand \( c_i(\bullet) \) and output \( q_i(\bullet) \) and equating them.

2. The household then examines whether, at the available market price, it would obtain higher utility as a buyer or seller by comparing indirect utilities at market prices net of transactions costs to the indirect utility at the shadow price.

3. The household then selects the optimal market regime. It becomes a seller if the market price is above the shadow price plus any transactions costs. It becomes a buyer if the market price is below the shadow price minus transactions costs.

In Figure 1, the shadow price itself, \( p^* \), for a given good \( i \) for which the household must make the market regime choice, is thus shown at the intersection of the optimal non-tradable consumption demand curve \( c_i(p_i, p_j, Y_t) \) and output supply curve \( q_i(p_i, p_j; \theta) \).

Any changes in consumption demand (due to changes in demand for tradables as examined above) or output supply (due to changes in the amount of output available, due to an incoming harvest, for example) will therefore alter the location of the shadow price.

For marketing regime choice, as can be seen in the Figure, for market prices between points B and C, the household optimally chooses autarky as it cannot obtain a higher utility through any type of market participation. For market prices between point A and B, the household’s best regime choice is as a seller of the good, as the market price is high enough to cover any transactions costs plus the internal shadow valuation of the good. Finally, for prices between points C and D, the best choice is as a buyer of the
good, since the market price is lower than the internal valuation minus any transactions costs incurred through market participation.

With a credit constraint, the household’s shadow price for a non-tradable good can potentially move in response to prices in tradables markets, and with it the overall supply response curve. Figure 2 illustrates a scenario where a household’s initial shadow price for a non-tradable good is very low, and the resultant output supply curve is shown as the ‘sell low’ line on the graph. Although the exact response of the shadow price to changes in consumption of the tradable good given by equation (4) is difficult to determine ex ante, when confronted in the data with households who sell their output for prices that are lower than observed purchase prices, we may imagine that this is partly due to a lowering of the shadow price for a non-tradable to the point that the entire supply response curve shifts downwards as shown by the ‘sell low’ graph. We imagine this to be the scenario for credit constrained farmers immediately after harvest. The difference between credit constrained and non-credit constrained farmers becomes apparent when we analyze the chosen marketing regime at the price level $Plow$. For the non-constrained farmers, the price $Plow$ falls within its non-tradables band and the non-constrained households optimally choose autarky. But for the households whose shadow price has fallen, either due to the credit constraint or a large harvest, at price $Plow$, their low shadow price for the good implies that it is still optimal to sell their commodity in the market, as $Plow$ falls within the sales region (points A’ and B’) for these households. Given the seasonal nature of commodity prices, which typically fall at harvest time,

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3 An unexpectedly large harvest will also produce this result, due to the dependence of the shadow price on both internal demand and supply.
farmers who also have a shadow value for a commodity that moves with the market price (as hypothesized by de Janvry et al) may thus find it optimal to sell their output, rather than remain in autarky.

At the other end of the spectrum, there may be households who have a very high internal shadow price for a given commodity, and their resultant supply response curve is shown in the ‘buy high’ graph. In particular, if we believe that a binding credit constraint leads to gradually increasing consumption of tradable goods due to the changing marginal utility of consumption induced by the liquidity constraint $\lambda_t$ (shown in equation (3)), then it is possible that credit constrained household’s supply curves will shift upwards during the interharvest period. In combination with a seasonal increase in prices during the interharvest period, the difference between credit constrained and non-constrained households can now be seen in the market participation decision around price $P_{\text{high}}$. Household’s whose shadow price has risen during the interharvest period due to the credit constraint will opt to enter the market as buyers at end of season high prices, with $P_{\text{high}}$ falling between points C’’ and D’’ for these households. Meanwhile, the non-constrained households, whose supply response curve has not changed due to their better ability to smooth consumption, have $P_{\text{high}}$ falling within the non-tradables region and continue to stay out of the market. Note that the only households who would be able to capitalize on the high end of season prices are those who are somehow able to keep their shadow prices low enough so that the price $P_{\text{high}}$ falls into the sales region.

The scenario presented above shows the probable marketing choices of constrained and non-constrained households when the liquidity constraint induces an initial reduction in the shadow price for non-tradables, followed by a gradual increase
during the interharvest period. However, as previously mentioned, the elasticity of non-tradable good’s shadow price with respect to any credit constraints that impact consumption in the tradables sector is the complicated function shown in equation (4) that represents the many conflicting forces that agricultural households operating in incomplete markets face. It is not possible at the outset to predict whether credit constraints may result in the above phenomenon without examining data on market transactions and attempting to isolate the impact of liquidity on these decisions. Assumptions about the relative strength of the different interactions of elasticities between current and future periods, as well as information on the formation of price expectations are also all key aspects of the decision making process that may affect the marketing outcomes observed.

**Estimation Strategy**

As a first pass at investigating the relationship between credit access and marketing decisions, a reduced form relationship between marketing decisions and the important correlates of these decisions, such as credit access, market prices, and transactions costs, must be developed. Goetz (1992) estimates a two stage decision-making process by first finding the correlates of market entry that are related to the household comparison of market and shadow prices. He then uses a subset of these correlates to predict the actual volumes transacted in the market, either as a purchase or a sale. He uses the first stage regression to counter the obvious selection bias that would result from analyzing only market participants and their characteristics in the overall market participation behavior. This is much like the selection correction that must be performed when analyzing labor market participants.
Goetz’ first stage regression is modeled as a bivariate probit to account for the correlation between sales and purchase decisions. We will use a procedure similar in spirit to Goetz’s first stage to examine the market participation of credit-constrained farmers. A key difference is that we will analyze market participation decisions both at harvest and in a post harvest period. As the calculation of the selection correction terms with a multivariate probit rather than a bivariate probit becomes difficult (and the consistency of existing two-step approaches with multivariate systems is up for debate (Shonkwiler and Yen 1999)), we will estimate the parameters via full information maximum likelihood, following a procedure similar to Dong, Chung and Kaiser (2004) and Bellemare and Barrett (2006). Given the predictions of the model given above, credit constrained households should be more likely to sell in the harvest period and purchase in the post harvest period, if their shadow price tracks the overall seasonal price swings between the two periods and in addition, the lack of credit impacts the variation in these shadow prices.

As an initial investigation, the rest of the following concerns the first stage ‘market entry’ decision, with the parameter estimates for quantities transacted reserved for future work. The set of market participation decisions is modeled as a multivariate probit, looking at average purchase and sale decisions in two periods – one defined as ‘harvest’ and the other as ‘post-harvest’.

Similar correlates apply to both sales and purchase decisions as they essentially involve the comparison of internal demand and supply pressure with market prices. As well, as was shown in the previous section, current period demand and supply functions are also functions of expected future price realizations, therefore these decisions are
necessarily correlated across time. The multivariate probit estimation technique will allow for estimation of this correlation.

The estimation will essentially examine the following set of four equations:

\[
\begin{align*}
(1) \quad b_h &= \begin{cases} 1 & \text{if } b^*_h > 0 \\ 0 & \text{o.w.} \end{cases} \\
(2) \quad s_h &= \begin{cases} 1 & \text{if } s^*_h > 0 \\ 0 & \text{o.w.} \end{cases} \\
(3) \quad b_{ph} &= \begin{cases} 1 & \text{if } b^*_{ph} > 0 \\ 0 & \text{o.w.} \end{cases} \\
(4) \quad s_{ph} &= \begin{cases} 1 & \text{if } s^*_{ph} > 0 \\ 0 & \text{o.w.} \end{cases}
\end{align*}
\]

where \(b_h(s_h)\) is a (0,1) binary variable indicating that a household is a buyer(seller) in the harvest period (subscript h), and \(b_{ph}(s_{ph})\) is an indicator for the household participating as a buyer(seller) in the post harvest period (subscript ph).

Furthermore, the latent values determining whether the buyer/seller indicators \(b_{h(ph)} \) and \(s_{h(ph)} \) are observed are given by:

\[
\begin{align*}
b^*_i &= \gamma_i z_i + \epsilon_i, \quad s^*_i = \beta_i x_i + \xi_i, \quad i \in \{h, ph\}, \\
E(\epsilon_i) &= E(\xi_i) = 0, \quad V(\epsilon_i, \xi_i) = \\
&= \begin{bmatrix}
1 & \rho_{12} & \rho_{13} & \rho_{14} \\
\rho_{21} & 1 & \rho_{23} & \rho_{24} \\
\rho_{31} & \rho_{32} & 1 & \rho_{34} \\
\rho_{41} & \rho_{42} & \rho_{43} & 1
\end{bmatrix}
\end{align*}
\]

with \(z_i\) as a set of associated correlates of market entry. Due to the potential for market sales and purchase decisions to be correlated across individuals over the interharvest period, the error structure allows for correlation between harvest and post harvest decisions, as shown in the non-zero off-diagonal terms, \(\rho_{h,ph}\) in the variance-covariance matrix \(V(\bullet)\) above.

**Data**
Data used come from a recent survey taken in western Kenya examining many aspects of household production and consumption behavior, as well as interventions into important commodity markets, including cereal banks, market information initiatives and a program designed to increase agricultural credit by extending credit to agricultural input retailers.

Most farmers in the sample engage in rain-fed agriculture, on farms less than 3 acres. Households grow maize and either sell or store it on the farm until it is either consumed or sold in the period between harvests. Typical storage facilities for agricultural output are either open bins constructed of wood or bamboo that are raised off the ground to protect the output from pests, or simply in bags inside the family home. In rare cases, a household will have a storage area for output that is constructed out of concrete. Households that are members of cereal banks store the output that is used as a share contribution at the cereal bank, which is typically a concrete structure in the local market place. Secure storage technology is therefore not available to many farmers in the sample and will be important as a control variable when explaining market participation decisions.

Monthly marketing patterns for maize, which is a staple food for most of Kenya, including sales and purchase prices and transaction volumes have also been recorded as well as information on the use of either agricultural or non-agricultural credit for different purposes over the course of the year preceding the survey. The survey design was choice based rather than a random sample to increase the observation of rare events (e.g. cereal bank membership), so all analysis has been appropriately reweighted to account for the sampling design. Summary statistics for the correlates used in the market participation analysis are included in Table 1.
Figure 3 illustrates the average sales and purchases behavior found in the data and demonstrates a number of key points\textsuperscript{4}. First, there is a high level of variation in prices and transaction volumes over the year, and some marked seasonality (the two vertical lines represent western Kenya’s two harvest periods) and also there exists a clear wedge between purchase and sale prices, most likely indicating the presence of transactions costs in the region of study. Figure 4 looks at similar data, but for credit and non-credit constrained households.

**Analysis**

Different behaviors for sales and purchases become apparent when we compare the estimated coefficients associated with the variables that determine market entry across the harvest and post-harvest periods, as given in Table 3\textsuperscript{5}. The dependency ratio is significant in both harvest and post-harvest periods for buyers and increases the probability of entering the market as a buyer, but does not influence the sales decision. Total land owned reduces the probability of entering the market as a buyer and increases the probability of entering as a seller in both the harvest and post-harvest periods, in line with the most likely larger maize harvests obtained for these farmers.

\textsuperscript{4} Note that averages in the monthly market graphs do not match sample averages due to the sampling design – the monthly means do not converge to the same value as the overall sample mean due to the reweighting.

\textsuperscript{5} Due to the number of households that do not report applying for credit, we estimate a probit model for credit access and use the predicted probability of credit as a regressor in the market participation estimation. The covariates used and the results of this estimation of predicted credit access are shown in Table 2.
Purchase price does not significantly influence the buying decision in either period, however sales price is significant but reduces the probability of entering the market as a seller, counter to expectations. However, the interaction term provides some interesting insight into this behavior – for households with credit, the sales price positively influences the probability of entering the market as a buyer, perhaps indicating that non-credit households are not able to take advantage of arbitrage opportunities to the same degree as households with credit.

A major alternative explanation for possible mis-timed market participation as described in this paper is the possibility that storage technology is essentially unavailable to the farmers in the survey and the costs of storing maize grain between periods is high enough that the low returns to sales in the harvest period are still less costly than storing and losing grain to spoilage etc. due to poor storage facilities. The farmer reported value of the household’s on-site storage facility was thus included in the regression. The storage variable does not appear to be significant in either of the buyer decisions, but it is significant and negative for sales decisions immediately after harvest and significant and positive in the post-harvest period, indicating some farmers are possibly using storage to arbitrage prices. However, the significance of the credit variable in addition to the storage variable for sellers in both periods shows that access to credit is an additional important covariate in the market participation decision. Particularly, credit access lowers the probability of sales in both time periods, possibly showing that households with credit can avoid sales at the low price that immediately follow the harvest and then for households that can hold on to their stocks until prices increase in the second period, maize sales are a substitute for credit for households without it, leading to their higher
sales probability in the second period. This warrants further exploration – aggregating sales decisions into two periods undoubtedly masks the dynamics of the participation decision.

**System dynamics model of household marketing decisions**

As a complement to the econometric analysis and as a tool for further exploring the consequences of different credit access levels, we have also developed a simple system dynamics simulation model of household marketing decisions that tracks changing shadow prices for non-tradable commodities during the interharvest periods and attempts to predict how households respond to different market price distributions.

The system dynamics approach links important stock variables together with various rate equations that determine the flows of physical quantities into and out of these stocks. The combination of the dynamics of several different stocks and the response of the flow rates to the stock levels produces feedback loops from the stock states to the rates of flow. The interaction of these feedback loops then generates the time path of key variables of interest.

In the case of farmer marketing decision making, the quantities of interest are sales and purchase quantities and prices of maize as well as the specific times when the household’s enter the market as either buyers or sellers. Given the theory presented previously on the impact of credit constraints on the household’s shadow price for maize, we hypothesize that a lack of liquidity will cause some households to sell their output at low prices and buy the same output back in the market at a later date for higher prices, while non-constrained households are more able to smooth their consumption.
Household decision making is modeled for approximately 20 weeks after a given harvest has been taken in by the household. This harvest provides an initial inflow to the household’s stock of maize. The household evaluates the shadow price of maize by equating the available stock to household demand for maize, which is assumed to be a function of both the shadow price for maize as well as the prices for other consumption goods (as per the optimal consumption functions $c_t(\bullet)$ given in equation (2)). The household gradually consumes its stock of maize during the interharvest period. The decrease in the available stock increases the shadow price. Depending on the prevailing market price and the instantaneous shadow price, the household either sells maize or buys maize in the market or chooses to remain in autarky. The final details of the simulation include the market price for maize slowly increasing during the interharvest period and also the household experiences a shock to consumption of tradable goods.

Figure 5 shows the resultant shadow price for maize for the simulated household model. As the harvest arrives at time zero, the increase in the household maize stocks lowers the shadow price. But the gradual consumption of maize over the time period in combination with the shock to other consumption gradually raise the shadow price.

The impact of the changing shadow price on sales and purchase decisions is shown in Figure 6. The household initially has a low shadow price for maize and this induces early sales, as shown by the red line on the graph. But eventually, the increasing shadow price causes the household to switch from being a seller of maize to a buyer. Although these patterns are qualitative rather than quantitative in nature, they illustrate the possibility that changing shadow prices will affect marketing decisions. The
simulation model will be further expanded to include different policy interventions, like increased credit availability and other market price distributions.

**Discussion and Conclusion**

The market participation behavior of smallholder farmers when faced with imperfect markets is a function of the shadow price for different commodities that a household both consumes and produces. While this is not a new concept, we have shown that in analyzing these participation decisions, one must also take into account the fact that the shadow prices for commodities may vary over time. Using a unique dataset that details the interharvest marketing behavior of small holders, we are able to show that credit constraints in the tradable sector may impact the market participation timing for Kenyan maize farmers. Our theoretical model also goes some way towards explaining the ‘sell-low’/’buy-high’ phenomenon, observed amongst many rural communities, as a function of changing shadow prices. This differs somewhat from the alternative explanations of this price differential as representative of quality differences and simply the existence of transactions costs. Our also explains why some households who operate in markets with regular seasonal patterns are not able to take advantage of arbitrage opportunities. Finally, to further disaggregate household decision making, we develop a system dynamics model of the agricultural output storage, sales and consumptions decisions and are able to replicate the ‘sell-low’/’buy-high’ phenomenon under reasonable assumptions on farmer decision making.

The possibility that liquidity constraints affect market participation is further evidence of the contribution of thin financial markets to rural poverty, in that farmers are using commodity markets and their knowledge of seasonal pricing patterns as a form of
quasi-credit. Further exploration of the relationship between marketing decisions and missing credit markets is thus warranted in the interest of finding useful policy directions to assist with escaping poverty.

Acknowledgements

We acknowledge with gratitude support from the Rockefeller Foundation, as well as the Tegemeo Institute of Agricultural Policy and Development. The views expressed here and any remaining errors are the authors’ and do not represent any official agency.

References


Figure 1. Hypothesized supply response curve and shadow price formation under proportional transactions costs

Figure 2. Supply response curves for credit constrained and non-credit constrained households
Figure 3. Maize sale and purchase quantities, overall sample (N=1682)

Households with credit

Households without credit

Figure 4. Average maize sales and purchase quantities by credit status (N_{credit}=524, N_{no credit}=1158)
<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Mean</th>
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<tr>
<td>Price (Ksh/kg):</td>
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<tr>
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Note: Average village, sublocation, location or district prices were used for households who did not participate in markets.

### Table 1. Summary Statistics

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Note: *** indicates significance of 5% or better. N=1679, Wald chi-sq(6)=39.90, Prob>chi-sq=0.000, Pseudo R-sq=0.0285.

### Table 1. Results of probit regression for access to either agricultural or non-agricultural credit
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Note: *=10%, **=5% ***=significant at the 1% level or better.
Likelihood ratio test of  \( \text{rho21} = \text{rho31} = \text{rho32} = \text{rho41} = \text{rho43} = \text{rho42} = 0 \) : \( \text{chi2}(6) = 226.32 \)
Prob > chi2 = 0.0000

**Table 3. Multivariate Probit Estimation of Market Participation Probabilities, Harvest and Post-Harvest Season N=1679 (N_{hb}=781, N_{hs}=546, N_{phb}=1281, N_{phs}=214)**
Figure 5. Simulated shadow price of maize during interharvest period

Figure 6. Simulated maize sales and purchase behavior during interharvest period
A. Derivation of current shadow price elasticity with respect to a change in the current relative price of tradable goods.

Let the shadow price of non-tradable goods at a particular period be represented by $p_{j,t}$ and let the price of any output sold or purchased in the market be represented by $p_{i,t}$. For simplicity to calculate the elasticity we are assuming that there is only one non-tradable and one tradable good that is consumed and produced by the household.

The shadow price is determined by the non-tradables resource constraint, (shown as part of equation (1)) at the optimal level of both consumption and production. Recall that the consumption demand and production output equations are functions of the current and expected future prices of both the tradable and non-tradable goods as well as current and expected full income, $Y_t$ in each period. Full income is defined as the value of all household production and labor, and in the intertemporal problem presented in this article, this also includes the value of any stored output that is carried over between periods, $ST_t$ as well as cash savings, $S_t$. Finally, the household labor income is evaluated at the market wage, $w$ for the total household labor endowment, $L_T$. Therefore, the non-tradable resource constraint at the optimal consumption and production levels can be written as:

$$c(p_{i,t}, E_t p_{i,t+1}, p_{j,t}, E_t p_{j,t+1}, Y_t, E_t Y_{t+1}) = q(p_{i,t}, E_t p_{i,t+1}, p_{j,t}, E_t p_{j,t+1}; \theta)$$

with $Y_t = p_{i,t} q_{i,t} + p_{j,t} (q_{j,t} + ST_{j,d} (p_{i,t}, p_{j,t}, Y_t)) + S_t (p_{i,t}, p_{j,t}, Y_t) + wL_T$

and $E_t Y_{t+1}$ is the expectation over uncertain future prices and output of $Y_t$. 


For the derivation, we omit the time subscripts for clarity. We also replace the expected future prices \( E_t p_{t+1} \) with the greek letter \( \pi \), appropriately subscripted for tradable and non-tradable goods, and expected future income \( E_t Y_{t+1} \) with the greek letter \( \Lambda \).

Total differentiation of equation (5) yields the following expression:\(^6\):

\[
\frac{\partial c}{\partial p_i} dp_i + \frac{\partial c}{\partial \pi_i} d\pi_i + \frac{\partial c}{\partial p_j} dp_j + \frac{\partial c}{\partial \pi_j} d\pi_j + \frac{\partial \pi}{\partial Y} \left( \frac{\partial Y}{\partial p_i} dp_i + \frac{\partial Y}{\partial p_j} dp_j \right) + \frac{\partial \Lambda}{\partial \pi_i} d\pi_i + \frac{\partial \Lambda}{\partial \pi_j} d\pi_j =
\frac{\partial q_j}{\partial p_i} dp_i + \frac{\partial q_j}{\partial \pi_i} d\pi_i + \frac{\partial q_j}{\partial p_j} dp_j + \frac{\partial q_j}{\partial \pi_j} d\pi_j
\]

To transform equation (6) into elasticity notation, we adopt the following abbreviations:

\[
\begin{align*}
\theta_{i,p} &= \text{consumption elasticity of good } i \text{ with respect to price } p \text{ (can be tradable or non-tradable good)} \\
\eta_{i,Y} &= \text{income elasticity of good } i \text{ with respect to full income } Y \text{ (can be tradable or non-tradable)} \\
E_{q,p} &= \text{output elasticity of good } q \text{ w.r.t. price } p \text{ (can be tradable or non-tradable good)} \\
\Theta_{i} &= \text{Elasticity of expected future price of good } i \text{ to current price of good } i \\
\gamma &= \text{ratio of consumption of non-tradable good } j \text{ to total non-tradable output } q_j \\
\alpha_{i} &= \text{income share of output good } i \text{ of current full income } Y \\
\delta_{i} &= \text{future expected income share of good } i \text{ in expected income } \Lambda \\
\mu_{j} &= \text{income share of stored good } j \text{ in current full income } Y \\
\nu_{j} &= \text{future expected income share of stored good } j \text{ in expected income } \Lambda
\end{align*}
\]

\(^6\) Note we are able to invoke the envelope theorem at the optimum consumption and production and are thus able to ignore the indirect effects of differentiating output, storage and savings.
Collecting all the terms with $dp_i$ and $d\pi_i$ onto the left hand side, and those with $dp_j$ and $d\pi_j$ and on the right, equation (6) becomes:

\[\frac{\partial c}{\partial p_i} dp_i + \frac{\partial c}{\partial \pi_i} d\pi_i + \frac{\partial c}{\partial Y} dp_i + \frac{\partial c}{\partial \pi_i} d\pi_i - \frac{\partial q_j}{\partial p_i} dp_i - \frac{\partial q_j}{\partial \pi_i} d\pi_i = \]
\[\frac{\partial q_j}{dp_j} - \frac{\partial q_j}{dp_j} - \frac{\partial c}{\partial p_j} dp_j - \frac{\partial c}{\partial \pi_j} d\pi_j - \frac{\partial c}{\partial Y} dp_j - \frac{\partial c}{\partial \pi_j} d\pi_j + \frac{\partial c}{\partial \Lambda} dp_j - \frac{\partial c}{\partial \pi_j} d\pi_j \]

Using the various elasticity constants defined above, the left hand side becomes:

\[\left(\Theta_{c,p_i} + \Theta_{c,\pi_i} + \Theta_{c,Y} \gamma \alpha_i + \Theta_{c,\Lambda} \gamma \delta_i \Theta_i - E q_j, p_i - E q_j, \pi_i \Theta_i \right) \frac{dp_i}{p_i} \]

and the right hand side becomes:

\[\left(E q_j, p_j + E q_j, \pi_j \Theta_j - \Theta_{c,p_j} \gamma - \Theta_{c,\pi_j} \gamma \Theta_j - \Theta_{c,Y} \gamma \alpha_j - \Theta_{c,\Lambda} \gamma \delta_j \Theta_j \right) \frac{dp_j}{p_j} \]

Therefore, the elasticity of the current shadow price $p_j$ to a change in a current market price $p_i$ can be written as:

\[\text{Elasticity}_{p_j,p_i} = \frac{\left(\Theta_{c,p_i} + \Theta_{c,\pi_i} + \Theta_{c,Y} \gamma \alpha_i + \Theta_{c,\Lambda} \gamma \delta_i \Theta_i - E q_j, p_i - E q_j, \pi_i \Theta_i \right)}{\left(E q_j, p_j + E q_j, \pi_j \Theta_j - \Theta_{c,p_j} \gamma - \Theta_{c,\pi_j} \gamma \Theta_j - \Theta_{c,Y} \gamma \alpha_j - \Theta_{c,\Lambda} \gamma \delta_j \Theta_j \right)} \]