Market timing and liquidity constraints: smallholder farmers in Mozambique*

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March 31, 2021

Abstract

This paper uses data on farmers' expected prices from a randomized survey of smallholder farmers in Mozambique for eight main crops. Survey data show that across all crops most interviewed farmers' expect prices to be higher in the lean season. Yet, farmers report selling most of their harvest shortly after harvest when prices are lower. We find that farmers store more of the harvested output if they expect higher prices, if the harvested output is lower, if storage quality is high, and if they are less liquidity constrained. The effect of expected prices on storage is larger for liquidity constrained farmers who indicate that they are responsive to prices. We develop an intertemporal model of market timing in the presence of liquidity constraints that is consistent with these findings.

Keywords: Liquidity constraints, market timing, price expectations, produce, storage, developing economies, household finance
JEL classification: D14, D15, D25, G51, O13, O16, Q11, Q12, Q14

*We would like to thank Manuel Matsinhe who helped with survey design and the team of research assistants Venancio Salegua, Jemusse Maugente, Joao Pedro, and Joao Nuvunga for their excellent data collection supervisory roles. Zavale, de Araujo, and Mosse are grateful for the financial support from the Norwegian Embassy in Mozambique, through the National Cooperative Business Association (NCBA) Cooperative League of the United States of America (CLUSA) managed PROMAC II project, which made this study possible. Albuquerque gratefully acknowledges financial support from the Foundation for Science and Technology-FCT under grant PTDC/EGE-OGE/30314/2017. Albuquerque is with Boston College (rui.albuquerque@bc.edu), ECGI, and CEPR, de Araujo is with Eduardo Mondlane University (baraujomz@gmail.com), Brandao-Marques is with the International Monetary Fund (lmarques@imf.org), Mosse is with Eduardo Mondlane University (gerivasiamosse@gmail.com), de Vletter (PVletter@ncbaclusa.net) is with NCBA CLUSA, and Zavale is with Eduardo Mondlane University (hzavale@gmail.com). The views expressed in this paper are those of the authors and do not reflect the views of the International Monetary Fund or those of NCBA CLUSA. All errors are our own.

1 Introduction

In many developing countries produce crops display low prices right after harvest and high prices later on in the lean season before the next harvest season starts (e.g., Stephens and Barrett 2011, and Burke, Bergquist, and Miguel 2019, and references therein). In the face of these patterns, it is somewhat puzzling that farmers in these countries, especially poorer farmers, sell most of their crop shortly after harvest. Starting with Barrett (2007) and Stephens and Barrett (2011), a prime argument for this behavior is that farmers face liquidity constraints. This paper contributes to this literature by developing and testing new predictions on how a liquidity constrained farmer behaves in response to both market conditions and harvested amount.

We develop a model of the optimal timing to sell a crop. The main premise of the model is that the farmer is faced with a desire to smooth consumption over time as in Stephens and Barrett (2011). When confronted with a price path that is back loaded, i.e., lower following harvest and higher in the lean season, an unconstrained farmer chooses to store all her harvest in order to take advantage of the high prices if potential losses from storage are not too large. What makes the farmer be unconstrained in the model is the liquid wealth the farmer has at the time of harvest that allows her to have high consumption after the harvest even without selling any of the harvested crop. In contrast, a constrained farmer must sell some of the crop immediately after harvest so as to smooth consumption optimally.

The model produces three main hypotheses from comparative statics exercises. First, a farmer that has higher liquid wealth at the time of harvest is less constrained and chooses to sell more of the crop later on. The next two results are novel and also somewhat less obvious. Second, a higher harvested amount makes the farmer feel more constrained and leads the farmer to sell more earlier on. The intuition for this result is that the good news for the farmer makes her want to consume more already at the time of harvest, which for a constrained farmer it is possible only by selling some of the harvested produce. And, third, the higher prices in the lean season make investors want to store more only if they have high elasticity of intertemporal substitution. To understand this last prediction, note that a higher future price carries two effects on consumption. By the income effect, the farmer is wealthier and would like to consume more at the time of harvest already, leading to less storage of the harvested amount. But, by the substitution effect, it is more advantageous to sell the crop later on. The substitution effect dominates when the elasticity of intertemporal substitution is high. Lastly, the model also produces the more standard result that farmers with poor storage also sell faster.

To test the model, we use survey data from a randomized sample of smallholder farmers in Mozambique. The survey, conducted in September of 2020, just before the lean season started, includes four provinces in Mozambique, Nampula, Zambezia, Sofala, and Manica, and covers eight crops, maize, peanut, bean, cowpea, pigeon pea, cassava, sesame, and soya bean. According to the 2016/2017 Integrated Agricultural Survey of Mozambique, these provinces represent over 50% of the total area cultivated in Mozambique in each of the crops with the exception of peanut with 36.4%, bean with 29.3%, and cowpea with 40.9%, and these eight crops account for 65.1% of the cultivated area in the same period (see Zavale et al. 2021).

The survey includes specific questions on the ability to time the market, such as the time it takes to sell the crop, prices obtained by farmers at the moment of sale, loss due to inadequate storage, reasons to sell early, and what we believe is a novel aspect of our survey, expectations of prices during the upcoming lean season. Figure 1 shows the histograms of farmers' expected price growth per crop in our sample. The histograms show that in all cases, the vast majority of farmers expect prices to be higher in the lean season ahead. This evidence is novel and is consistent with actual price paths reported in other studies, suggesting that the farmers in our sample are well aware of the usual market price dynamics. Importantly, we also asked farmers about how much more they would store had they known that prices would go up by 20% in one month. This question provides an indication of the farmers' subjective elasticity of storage to prices, which we use to investigate the consistency of our results since we expect these to apply only to those farmers that indicate being sensitive to prices.

[Figure 1 here]

Our regression results reveal that storage decisions of smallholder farmers in Mozambique are consistent with all three main predictions. More liquidity constrained farmers, farmers with poorer storage conditions, and farmers with larger crop outputs sell their crops faster, closer to the harvest season, whereas farmers expecting higher price growth tend to sell their crops later in the season. The regressions control for a host of variables including demographic characteristics of farmers, i.e., the age, gender, and education level of the household head, the frequency with which farmers obtained price information.

We then interact the variable expected price growth with the farmer's disclosed elasticity of storage to price. We find that the variable expected price growth is not statistically significant, except when interacted with a dummy variable that indicates a high elasticity. The effect of the interacted variable is larger than the effect of expected price growth alone. These results suggest that the farmers in our survey understand price variations over time and choose not to time these due to liquidity constraints. Finally, we show that the significance of the sensitivity of storage to expected price changes is higher when the farmer is more liquidity constrained.

In related literature, Stephens and Barrett (2011) show that households with access to liquidity, either in the form of off-farm income or debt, avoid selling low in the harvest season and store to be able to sell when prices are higher. Fink, Jack, and Masiye (2018) show that liquidity constrained farmers are forced to offer off-farm labor to meet their expenses. Omotilewa, Ricker-Gilbert, Shively, and Ainembabazi (2016) also find that higher cash on hand is associated with higher storage. Kadjoa, Ricker-Gilbert, Abdoulaye, Shively, and Baco (2018) show that liquidity constraints affect households that store for own consumption but not those that store to sell in the market. Sun, Qiu, Bai, Liu, Lin, and Rozelle (2013) show evidence of liquidity constraints only among poor households. Burke, Bergquist, and Miguel (2019) document that in a randomized trial, farmers offered a loan after harvest stored significantly more maize in order to sell later at higher prices. Our paper complements this literature by offering a new prediction on how expected price growth post harvest is linked to storage by liquidity constrained farmers and by providing evidence in support of this prediction.

There is a large literature on corporate investment in inventories. Here, we cite only two papers for brevity to illustrate that the storage decisions at the household level, a novel aspect of household finance, and at the corporate level appear quite different. In the U.S., Dasgupta, Li, and Yan (2019) document that financially constrained firms hold more inventory than unconstrained firms. Kashyap, Lamont, and Stein (1994) document that as the cost of carry increases, inventories decrease. The first of these observations stands in contrast with our findings for farmers. The second illustrates the differential nature of the considerations of firms and households. The former cares more about interest rates, the latter cares more about consumption smoothing in the face of significant intertemporal price variation.

This paper is also related to a literature where financial constraints interact with product market decisions. In the not-for-profit sector, Adelino, Lewellen, and McCartney (2018) show that hospitals decreased investment significantly after the 2008 financial crisis. Philios and Sertsios (2013) show that product quality decreases in financial distress in the airline industry. Mendes (2020) shows that financially constrained firms change their product mix toward products with short cash flow maturity. Granja and Moreira (2020) show that firms reduce product innovation after the great recession.

The paper proceeds as follows. The next section develops a model of market timing in the presence of liquidity constraints and derives the paper's main hypotheses. Section 3 describes the survey data used in the tests. Section 4 details the empirical specification and Section 5 describes the results from our hypotheses testing. Section 6 concludes the paper.

2 A simple model of farmers' market timing

We model a smallholder farmer that faces a standard consumption and savings problem and decides when to sell her crop. Time is discrete and indexed by subscript $t = 0, 1, 2, ...$ The farmer is assumed to live for an infinite number of periods. Denote consumption at time t by c_t, and let the period utility function be $c_t^{1-\gamma}/(1-\gamma)$, where $\gamma > 0$ is the coefficient of relative risk aversion.[1] The farmer discounts future utility at the rate $\beta < 1$.

We assume that period $t = 0$ is the harvest period when the farmer obtains $y_0 \geq 0$ units of the crop. For simplicity we assume that the farmer has no additional future harvests.[2] For any $t \geq 1$, the farmer starts with real money balances $m_{t-1} \geq 0$, and stored units of the crop $y_{t-1} \geq 0$. The farmer may choose

[1]When $\gamma = 1$, the period utility function is $\ln(c_t)$.

[2]In the model, there is no cycle of harvest seasons. We return to this issue below.

to sell the quantity $s_t \geq 0$ of her crop in period t at price p_t, in which case her money balances next period are

$$m_t = m_{t-1} + s_t p_t - c_t. \tag{1}$$

The price of the consumption good is normalized to 1, so p_t is the price of the crop in units of the consumption good. Implicit in this formulation is that the consumption good is a bundle of goods and cannot be substituted for by the crop. We shall solve the farmer's problem under different assumptions about the price process. For now, we assume that the price process is deterministic. Without loss of generality, we assume that the farmer does not have access to an interest-bearing account.

The stock of the farmer's crop next period is

$$y_t = (1 - \delta)\, y_{t-1} - s_t, \tag{2}$$

where $\delta > 0$ is the depreciation caused by an imperfect storage technology. Depreciation can be due to poor humidity conditions, pests, or theft.

Formally, the farmer's problem at any time $t \geq 1$ is to solve

$$U(m_{t-1}, y_{t-1}; p_t) = \max_{m_t, y_t, c_t, s_t \geq 0} \left\{ \frac{c_t^{1-\gamma}}{1-\gamma} + \beta U(m_t, y_t; p_{t+1}) \right\}, \tag{3}$$

subject to the constraints (1) and (2).

In the next subsections, we solve different versions of this problem assuming different price patterns.

2.1 Trading in a flat market

Suppose that $p_t = p > 0$ for all $t \geq 1$. If the farmer sells one unit of the crop produce at t, she receives p. Instead, the farmer can save that unit to sell at $t+1$. Because of imperfect storage, at $t+1$ she'll have only $1-\delta$ units to sell at the same price p, so she receives $(1-\delta)\,p$. Thus, with constant prices, it is optimal to sell the entire crop immediately. If the farmer starts with y_0, then optimal sales are $s_1^* = (1-\delta)\, y_0$,[3] and optimal money balances are

$$m_1^* = m_0 + (1-\delta)\, y_0 p - c_1. \tag{4}$$

[3]An '*' is used to denote optimality of the variable.

Problem (3), at $t = 1$, can be rewritten as

$$U(m_0, y_0; p) = \max_{c_1 \geq 0} \left\{ \frac{c_1^{1-\gamma}}{1-\gamma} + \beta U(m_0 + (1-\delta) y_0 p - c_1, 0; p) \right\}. \tag{5}$$

Note that from period $t = 2$ onward the farmer has no crop to sell, i.e., $y_t^* = 0$, for all $t \geq 1$. Since there is no more crop to sell, optimal sales are $s_t^* = 0$ for all $t \geq 2$. The problem then is one of how to consume the money balances over time. At any time $t \geq 2$, let $V(m_{t-1}) \equiv U(m_{t-1}, 0; p)$. Thus

$$V(m_{t-1}) = \max_{c_t, m_t \geq 0} \left\{ \frac{c_t^{1-\gamma}}{1-\gamma} + \beta V(m_t) \right\},$$

subject to

$$m_t = m_{t-1} - c_t.$$

This problem is the classical cake-eating problem. The solution to it is well known and it can be verified that for any m_t,

$$V(m_t) = \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \frac{m_t^{1-\gamma}}{1-\gamma},$$

and that optimal consumption is to always consume a constant fraction of money balances

$$c_t^* = \left(1 - \beta^{1/\gamma}\right) m_t,$$

and optimal money balances decline monotonically

$$m_t^* = m_{t-1} - c_t^* = \beta^{1/\gamma} m_{t-1}.$$

To conclude, if at time $t = 0$ the farmer has wealth $m_0 + (1-\delta) y_0$ and the consumption rule is to consume the fraction $(1 - \beta^{1/\gamma})$ of wealth, then lifetime utility at time 0 is

$$\begin{aligned} U(m_0, y_0; p) &= \max_{c_1 \geq 0} \left\{ \frac{c_1^{1-\gamma}}{1-\gamma} + \beta V(m_0 + (1-\delta) y_0 p - c_1) \right\} & (6) \\ &= \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \frac{(m_0 + (1-\delta) y_0 p)^{1-\gamma}}{1-\gamma}. & (7) \end{aligned}$$

2.2 Market timing by an unconstrained farmer

We assume the farmer solves her decision problem facing the following price path.

Definition 1 *Let $t = 0$ be the harvest period. The market timing price path is $p_1 = q$ and for $t \geq 2$, which we interpret as the lean season, $p_t = p$, with $q < (1-\delta) p$.*

To motivate this price path, we continue to assume that period $t = 0$ corresponds to the harvest period and period $t = 2$ corresponds to the lean season. This price path has been extensively documented (Stephens and Barrett 2011, Sun et al. 2013, Burke et al. 2019, and Kadjoa et al. 2018). In the alternative path where $q > (1-\delta) p$, the farmer chooses to sell all of the crop at time $t = 1$ taking advantage of the high price. This alternative path would not have represented a puzzle given the tendency for farmers to sell shortly after harvest.

In this subsection, we assume the farmer has high enough money balances that she will not be liquidity constrained

$$m_0 \geq \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p. \tag{8}$$

Lifetime utility at the start of time $t = 2$ is

$$U(m_1, y_1; p) = \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \frac{(m_1 + (1-\delta) y_1 p)^{1-\gamma}}{1-\gamma}, \tag{9}$$

because from $t = 2$ onward the farmer faces a market with a flat price forever; a problem we solved for in the previous subsection.

At time $t = 1$, using constraints (1) and (2), the farmer solves

$$\begin{aligned} & U(m_0, y_0; q) \\ = \; & \max_{c_1, s_1} \left\{ \frac{c_1^{1-\gamma}}{1-\gamma} + \beta \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \frac{(m_0 - c_1 + s_1 q + (1-\delta)((1-\delta) y_0 - s_1) p)^{1-\gamma}}{1-\gamma} \right\}. \end{aligned} \tag{10}$$

The unconstrained farmer can perfectly time the market and take advantage of higher prices in the future by postponing sales til time $t = 2$. Thus, it is optimal to set $s_1^* = 0$. Substituting the solution for optimal sales into (10) and taking the first order condition with respect to consumption yields the interior solution

$$c_1^* = \left(1 - \beta^{1/\gamma}\right)\left(m_0 + (1-\delta)^2 y_0 p\right). \tag{11}$$

For this solution to be optimal it must satisfy the non-negativity constraint on money balances going forward

$$m_1^* = m_0 - c_1^* \geq 0,$$

which holds if initial money balances satisfy condition (8).

2.3 Market timing by a liquidity constrained farmer

The farmer faces a market timing price path, but in this subsection, we assume the farmer is liquidity constrained in that at beginning of time $t = 1$ the farmer's money balances are $\left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p > m_0 > 0$, and constraint (8) binds. The farmer is more likely to be constrained when she has a better harvest of the crop (y_0 is high), faces high future prices, has better storage technology (low δ), or is less patient (low β).

With a liquidity constraint, some of the crop must be sold at time $t = 1$, constraining the ability of the farmer to time the market perfectly. The farmer's problem is to solve

$$\begin{aligned} & U(m_0, y_0; q) \\ = & \max_{c_1 s_1 \geq 0} \left\{ \frac{c_1^{1-\gamma}}{1-\gamma} + \beta\left(1-\beta^{1/\gamma}\right)^{-\gamma} \frac{\left(m_0 - c_1 + s_1 q + (1-\delta)\left((1-\delta) y_0 - s_1\right) p\right)^{1-\gamma}}{1-\gamma} \right\}, \end{aligned}$$

with the constraint that money balances are non-negative

$$m_1 = m_0 - c_1 + s_1 q \geq 0.$$

We again use the fact that from $t = 2$ onward the market faces a flat price forever and has lifetime utility (9).

Since the unconstrained optimum choice for consumption violates the non-negativity condition on money balances, the optimum constrained consumption must imply that money balances next period at optimally set to zero. We may therefore eliminate c_1 from the problem and write it as a problem to determine how much to sell in period $t = 1$. The farmer's problem becomes

$$U(m_0, y_0; q) = \max_{s_1 \geq 0} \left\{ \frac{(m_0 + s_1 q)^{1-\gamma}}{1-\gamma} + \beta \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \frac{((1-\delta)((1-\delta) y_0 - s_1) p)^{1-\gamma}}{1-\gamma} \right\}.$$

Taking the first order condition with respect to s_1 yields an equation that can be solved for the optimal interior value of sales, s_1^*,

$$q \left(m_0 + s_1^* q\right)^{-\gamma} = (1-\delta) p\beta \left(1 - \beta^{1/\gamma}\right)^{-\gamma} \left((1-\delta)\left((1-\delta) y_0 - s_1^*\right) p\right)^{-\gamma}.$$

Selling an extra unit of the crop today yields q units of the consumption good and each unit of the consumption good increases utility by $\left(m_0 + s_1^* q\right)^{-\gamma}$. The cost of selling that extra unit of the crop today is that the farmer gives up the ability to sell it tomorrow and get $(1-\delta) p$ units of the consumption good, where a unit of consumption increases utility by $\beta(1-\beta^{1/\gamma})^{-\gamma} \left((1-\delta)\left((1-\delta) y_0 - s_1^*\right) p\right)^{-\gamma}$. Solving for s_1^* yields

$$s_1^* = \frac{\left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)(1-\delta) y_0 - \frac{m_0}{q}}{1 + \left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)}.$$

Notice that for s_1^* to be an interior solution two conditions must be met. First, the farmer cannot sell more than the stored crop, $(1-\delta) y_0 \geq s_1^*$, which can be verified that it holds for all parameters. Second, $s_1^* \geq 0$, which can be verified happens for initial money balances $m_0 \leq \left[\frac{(1-\delta)p}{q}\right]^{-\frac{1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p$; for all other values of initial money balances, the farmer chooses to sell nothing at $t = 1$.

Next we analyze the properties of s_1^*. Not surprisingly, s_1^* declines with money balances, m_0. It is optimal to save the entire crop if money balances are high enough since $(1-\delta) p > q$; thus, more crop is stored if the farmer starts with higher money balances. Also, higher crop, y_0, implies that more of it is sold at $t = 1$. A higher crop implies higher income for the farmer, but the liquidity constraint limits the farmer's ability to take advantage of it already at $t = 1$; by selling more, the farmer achieves higher consumption smoothing.

The effect of the price tomorrow p on sales is more subtle. There are two effects from an increase in p: by the substitution effect, the farmer sells more at $t = 2$ when prices are higher; by the income effect, the farmer sells more at $t = 1$ to achieve greater consumption smoothing if p increases. When $\gamma < 1$, the substitution effect dominates. In this model there is no uncertainty, so γ plays the role of the elasticity of intertemporal substitution (EIS), where $EIS = 1/\gamma$. Thus, the substitution effect dominates for high values of the EIS.

At the interior solution for sales for the liquidity constrained farmer, stored crop equals

$$\begin{aligned} y_1^* &= (1-\delta)\, y_0 - s_1^* \\ &= \frac{(1-\delta)\, y_0 + \frac{m_0}{q}}{1 + \left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)}. \end{aligned}$$

At $t = 2$, the farmer sells all her remaining crop immediately since the price will stay constant from $t = 2$ onward. Thus

$$\begin{aligned} s_2^* &= (1-\delta)\, y_1^* \\ &= (1-\delta) \frac{(1-\delta)\, y_0 + \frac{m_0}{q}}{1 + \left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)}. \end{aligned}$$

2.4 Model predictions

We start by summarizing the discussion of the model with market timing price path. The next proposition combines the solutions for the case from subsection 2.2 with an unconstrained farmer (i.e., money balances are $m_0 \geq \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p$), and for the case from subsection 2.3 with a liquidity constrained farmer (i.e., $m_0 < \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p$).

Proposition 1 *The time $t = 1$ optimal consumption and sales under market timing, denoted by $\left(c_1^m, s_1^m\right)$, for a farmer starting with (m_0, y_0) are,*

$$s_1^m = \begin{cases} \frac{\left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma}-1\right)(1-\delta) y_0 - \frac{m_0}{q}}{1+\left[\frac{(1-\delta)p}{q}\right]^{\frac{\gamma-1}{\gamma}} \left(\beta^{-1/\gamma}-1\right)} & , m_0 \leq \left[\frac{(1-\delta)p}{q}\right]^{-\frac{1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p \\ 0 & , else \end{cases}, \qquad (12)$$

and

$$c_1^m = \begin{cases} m_0 + s_1^m q & , m_0 \leq \left[\frac{(1-\delta)p}{q}\right]^{-\frac{1}{\gamma}} \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p \\ m_0 & , else \\ \left(1 - \beta^{1/\gamma}\right)\left(m_0 + (1-\delta)^2 y_0 p\right) & , m_0 \geq \left(\beta^{-1/\gamma} - 1\right)(1-\delta)^2 y_0 p \end{cases}. \qquad (13)$$

Our main proposition states comparative statics on s_2^m/s_1^m, a ratio that indicates how the farmer wishes to postpone sales for later in the season. These results follow from comparative statics on s_1^m, because $s_2^m = (1-\delta)\left((1-\delta)\,y_0 - s_1^m\right)$, and so $s_2^m/s_1^m = (1-\delta)\left((1-\delta)\,y_0/s_1^m - 1\right)$.

Proposition 2 *Under the market timing price path:*

1. *A liquidity constrained farmer sells relatively more later in the season:*
    - *(a) if her money balances are higher;*
    - *(b) if her harvest output is lower;*
    - *(c) if the price later in the season increases and the farmer has high elasticity of intertemporal substitution.*
2. *A liquidity unconstrained farmer stores all her crop to sell later in the season.*

These results constitute our main hypotheses to be tested below. Note that quality of storage has two effects on sales at time $t = 1$. Better quality of storage has an effect similar to price growth (via $(1-\delta)p/q$), leading to higher storage. This is the usual model prediction relating storage to the quality of storage. In the current setup where storage decisions are part of a consumption and savings problem, better quality of storage also increases the initial harvest output (via $(1-\delta)y_0$), and this effect works against the initial effect (see Proposition 2).

2.5 Discussion

The model is stylized in several dimensions. Here we discuss the implications of alternative assumptions to the model. First, suppose the farmer cultivates multiple crops instead of just one. A constrained farmer picks the produce with lowest expected price growth to sell first in order to induce consumption smoothing. Again, higher expected price growth would be associated to higher storage for the farmer.

Second, suppose the farmer has some off-farm income. This income accumulates to the initial liquid wealth that the farmer brings into each period making the farmer less constrained. Thus, all else equal, a farmer with greater off-farm income chooses to optimally store more of the harvest to better time the market.

Third, the farmer in the model cannot borrow or lend. If the farmer could borrow risk free, she would be willing to do so at any interest rate that is below $(1 - \delta)p/q$. Intuitively, at this rate or lower the farmer can borrow against the income that she will attain once the prices increase. Given the large expected price changes, why don't we see more borrowing going on? Alternatively, what market frictions prevent borrowing from occurring?

Fourth, we have model only one harvest cycle when in fact harvest cycles repeat themselves. It would be be straightforward to add harvest cycles in the model, though at the cost of some complexity and without any additional insight. The restart of another cycle bringing more crop output changes the threshold on money balances for a farmer to qualify as unconstrained, but otherwise it does not significantly change the main predictions.

3 Data

The empirical tests use data from a survey of 443 smallholder farmers in Mozambique covering the 2019/2020 agricultural season (see Zavale et al. 2021, for full details on the survey). The survey was conducted between September 6 and September 30, 2020, and we note that the lean season in Mozambique starts in October.

The survey covers 13 districts in four provinces, Manica and Sofala in the Beira Development Corridor, and Zambezia and Nampula in the Nacala Development Corridor, in central and northern Mozambique, respectively. Data were collected on eight crops, namely maize, peanut, bean, cowpea, pigeon pea, sesame, soya bean, and cassava. These crops are among the priority crops identified under the Plano Operational para o Desenvolvimento Agrário (Operational Plan for Agricultural Development) for the Beira and Nacala Corridors and make up a significant portion of crops grown and marketed by smallholder farmers in Mozambique. According to the Integrated Agricultural Survey of Mozambique, in 2016/2017 these provinces represented over 50% of the total area cultivated in Mozambique for maize, pigeon pea, sesame, soya bean, and cassava, whereas for peanut, bean, and cowpea they represented, respectively, 36.4%, 29.3%, and 40.9% of the cultivate area. Overall, the eight crops studied account for 65.1% of the cultivated area in the same period.

The survey was constructed using a two-stage sampling procedure. As Zavale et al. (2021) explain, in a first stage, two administrative posts per district were selected based on their biophysical potential for the eight chosen crops. In a second stage, we randomly sampled smallholder farm households from the list of farm households in the named administrative posts.

The survey contains household demographic characteristics and data on eight crops: maize, peanut, bean, cowpeas, pigeon pea, sesame, soya bean, and cassava. The survey includes information on whether each farming household produced each crop, how much each crop was produced, the resources farmers had available for production (including storage), and the share of each crop sold to markets. Importantly, the survey also asked farmers about sale prices, the expected price for each crop 30 days after the survey (that is, already into the lean season), how long farmers waited to take their crop to market, and the number of weeks farmers would have been able to postpone selling the crop had that allowed the farmer to attain 10 or 20 percent higher prices.

[Table 1 here]

Table 1 presents summary statistics on the variables extracted from the survey used in this study. Table A1 presents the variable definitions. The average number of weeks that it took to sell the harvested output is 3.4. The output variable is denoted in logarithms of kilos. The price ratio variable represents the ratio of a farmer's expected price 30 days after the interview (in Mozambican meticais per kilo) to the price at which the crop was sold (in Mozambican meticais per kilo). The expected price was on average 16% higher than the actual price of sale. The own consumption dummy takes the value of 1 if most of crop is destined for own consumption. On average, across all crops, 57% of farmer crop pairs are for own consumption. The information on each of the variables above exists for each farmer and crop pair for which the farmer sold the crop.

The next variables are constructed at the household level. The poor storage variable is a dummy that takes the value of 1 if the farmer reports storage conditions as either fair or poor. About 70% of farmers indicate having poor storage conditions. The variable liquidity constraint is a dummy that takes the value of 1 if farmer did not buy seeds. The idea is to capture the availability of cash for seeds, an input that most farmers recognize as critical for a successful harvest. The vast majority of the surveyed farmers (85%) are classified as liquidity constrained. The variable price information is a dummy that takes the value of 1 if the farmer gets information on prices at least once a week. Surveyed farmers appear well informed as 41% of farmers indicating receiving regular price information. Finally, crop concentration is the Hirschman-Herfindahl index of share of total cultivated surface of each crop. A high value of crop concentration indicates a greater dependence on a smaller number of crops and less diversification of farm income.

Table 2 describes the average price ratio per crop and province. Across all crops, the highest average price ratio is for maize. Farmers expect on average the price of maize to be about 31% higher in 30 days after the interview, already into the lean season. Nuts, bean, and sesame also have high expected price jumps relative to the price at the time of sale. Overall, the information from Figure 1 and Table 2 show that higher prices in the lean season are a pervasive phenomenon by crop and province for all farmers.

[Table 2 here]

Table 3 give the correlation matrix for the variables used in the study. It is worthwhile noting that farmers with larger harvest output also tend to sell at lower prices. This may be because storage conditions limit farmers' ability to hold on to a large output and force them to sell at worse prices. In what we do later, it is therefore important to control for storage conditions (see also Stephens and Barrett 2011). There is a large positive correlation of the actual price with the expected price: farmers that sold at higher prices expect prices to go up later in the season. This is an indication that even those farmers that seemed to have done well, may be constrained if they sold at prices significantly below their expectations. The age of the head of household is negatively correlated with the schooling level of the household head:

older households tend to have less schooling.

[Table 3 here]

4 Empirical specification

We test the model's main predictions using a parametric hazard model approach. The dependent variable is the time it takes the farmer to sell a crop, given that that the farmer is producing and selling that crop. In the survey, for each crop, farmers were asked how long it had taken them to sell the entire output and were given six possible answers: less than 2 weeks, between 2 and 4 weeks, between 4 weeks and 2 months, between 2 and 3 months, between 3 and 4 months, and other (possibly more than 4 months). Figure 2 plots, for each crop, the percentage of farmers that reply affirmatively to each of the time periods above. Clearly, the vast majority of farmers that sell their crops do so in less than two weeks after the harvest, especially for maize, bean, cowpea, pigeon pea, sesame, and soya bean. It is noteworthy that the survey was conducted in September of 2020, several months past the harvest season and one month before the start of the lean season. At the time of the survey, most farmers who say they sold their crop, have sold all they wanted to.

[Figure 2 here]

With these data we build a categorical variable which defines the time to sell as intervals in terms of weeks. A higher value of this variable means that the farmer stores the crop for a longer period. We take this variable to be the empirical counterpart to s_2/s_1 from the model.

We estimate a parametric model for interval-censored survival data with a proportional-hazards parameterization. The hazard rate function for the time to sell t is:

$$h_j(t) = h_0(t)\exp(-x_j\beta), \tag{14}$$

where $h_0(t) = \alpha y^{\alpha-1}$ is given by the Weibull distribution and x_j is a vector of explanatory variables and controls and $j = (f, c)$ is defined in terms of farmer f and crop c. As is standard, the survivor function solves $h_j(t) = -\frac{dlogS_j(t)}{dt}$. The model is estimated by maximum likelihood where the likelihood function

$\mathcal{L} = \prod_{j=1}^{N} (S_j(t_{i-1})h(t_i))^{y_{j,i-1}} S_j(t_{i-1})^{1-y_{j,i}}$ is adjusted to account for the fact that the data are grouped into intervals ($i - 1 < t < i$), with $y_{j,i} = 1$ if the farmer sells the crop in that interval. The explanatory variable we are most interested in is the *expected price growth*, which corresponds to p/q in the model of Section 2. The second variable for which we have a testable implication in the model total output by crop (in logs). The other two main explanatory variables in the empirical model are storage conditions (*poor storage*) and the measure of liquidity constraints. The benchmark specification also includes crop fixed effects, to which in some cases we add province fixed effects or crop times province fixed effects. A positive coefficient implies that an increase in the corresponding variables increases the time to sell the crop (i.e., duration).

We therefore predict that duration (hazard rates) decrease (increase) if the farmer is liquidity-constrained, with the size of the crop, and if storage conditions are poor. We also predict that the duration (hazard rate) increases (decreases) with increases in expected prices.

5 Results

Table 4 presents the baseline regressions from estimating equation (14). The regressions are conducted at the farmer-crop observation level. Each column presents the results from a different specification of the set of control variables with column (6) having all the controls, plus crop fixed effects, province fixed effects, and crop times province fixed effects. These fixed effects are meant to capture unobserved characteristics by crop and province. For example, local weather conditions may have affected farmers of a certain crop in a given province relative to other farmers. Likewise, road conditions may facilitate trade differentially across provinces.

[Table 4 here]

The main result is that a higher expected price growth is associated with the farmer taking longer to sell the crop. This result is consistent with the model prediction in Proposition 2 assuming the farmer has high elasticity of intertemporal substitution (the assumption is common in models of asset pricing as in Bansal and Yaron 2004). The coefficient is significant even after including crop times province fixed effects. The rest of the coefficient estimates are also in accordance with the model's main predictions. Poor storage conditions lead the farmer to sell faster, and a liquidity constrained farmer also sells faster and stores less. The coefficient on crop output is highly significant and negative, that is, higher harvest output is associated with less storage. While this may seem a puzzling result, in the model it comes through because of the need to do consumption smoothing: more harvest output is good news for the farmer that knows that she'll be able to afford higher consumption in the lean season as she sells her crop at higher prices then, which also implies that she would like to increase consumption earlier which she can do by selling her crop faster.

Table 5 presents additional controls as a way to assess the robustness of the main findings to alternative hypotheses. We drop the crop and crop and province fixed effects in these regressions. Overall, the results indicate that the effects from Table 4 continue to hold. As would be expected, own consumption drives less storage (column 1), but having more frequent price information drives more storage (column 2). Selling at own farm gate (point of sale dummy) is insignificant indicating that transportation costs may not be a significant role for the storage decision once controlling for the other variables (column 3). The variable that indicates crop concentration is insignificant, suggesting that the lack of product diversification is not a factor for the storage decision (column 4). Along the demographic variables, male household heads tend to store more, and household heads with less schooling also tend to store more (column 5).

[Table 5 here]

Table 6 repeats the regressions in Table 4 but includes in the regressions interaction terms between expected price growth, the reported elasticity of storage, and the liquidity constraint dummy. The first three columns expand the results in Table 4 by including the interaction of expected price growth with the reported elasticity of storage. We note that the results are only significant for those households that in fact indicate that their storage decisions would respond to price changes. The remaining 3 columns add the triple interaction with the liquidity constraint dummy. While it is likely that all the smallholder farmers in the sample are liquidity constrained, by identifying those that did not buy seeds as especially constrained farmers, we tighten the test of the model hypotheses. Our results indicate that the effects are concentrated on those farmers that are particularly cash constrained and that have signaled that their storage would respond to price changes. Overall, this constitutes strong evidence in favor of the model's predictions.

[Table 6 here]

We present a final set of results. Table 7 splits the expected price growth into its numerator, the expected price, and its denominator, the price at which the farmer currently sold her crop, the actual price. In the first three columns we see that our main effect appears to come only from the actual price. Specifically, we find a negative coefficient associated with the actual price, suggesting that farmers that are able to obtain higher prices today sell faster. The last three columns indicate that when we interact the expected price with the elasticity, the farmers that indicate being responsive to prices in their storage decisions, indeed have more storage in response to higher expected prices consistent with the theory.

[Table 7 here]

6 Conclusion

This paper documents that smallholder farmers in rural Mozambique are well aware of market conditions: they understand that prices are generally higher in the lean season viz-à-viz the harvest season. Yet, they fail to to store their crops log enough to capture the higher prices occurring in the lean season in order to meet the consumption needs right after the harvest season. We document that the amount of produce stored increases with the expected growth in prices toward the lean season, decreases with the crop's output, and increases with the liquid wealth of the farmer. All of these effects are consistent with the model of liquidity constrained farmers that we develop.

How much income is it necessary so as to observe that farmers capture market conditions better? Several papers have advanced our knowledge on these question (e.g., Basu and Wong, 2015, and Burke et al, 2018). More research is needed to follow the wealth patterns of farmers over time as they attempt to leave the vicious cycle of low wealth and low ability to market timing. After all, farmer wealth correlates with usage of yield-enhancing inputs and with productivity of farm land.

More research can also be done on the causes of the price patterns observed in the data. One possible reason for prices to be lower earlier in the season is that buyers are aware of the liquidity constraints of farmers and their low bargaining power. Another is associated with the costs of storage and the limited capacity at the time of harvest. Also, more research should be dedicated to understanding the role that farmer associations can play in alleviating the inability to market timing.

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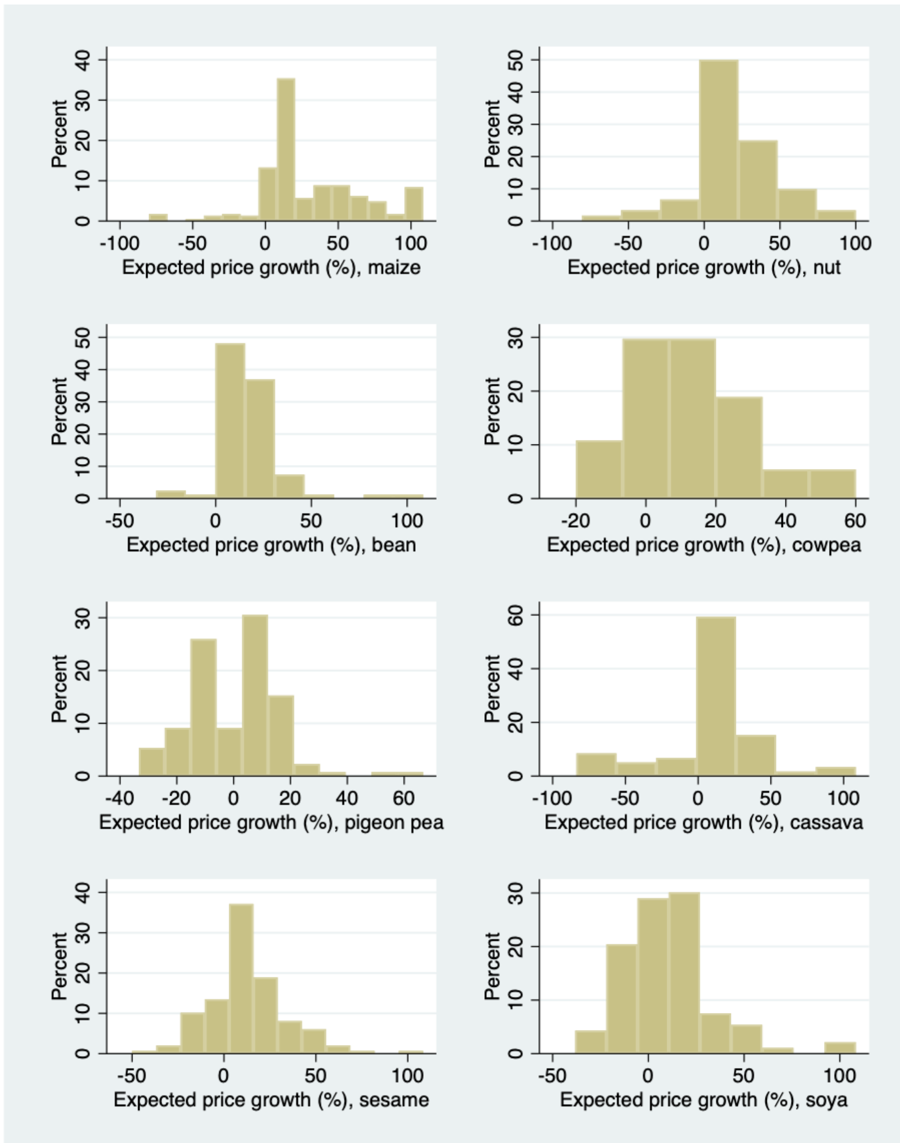

Figure 1: Histograms of farmers' expected price appreciation 30 days after the survey

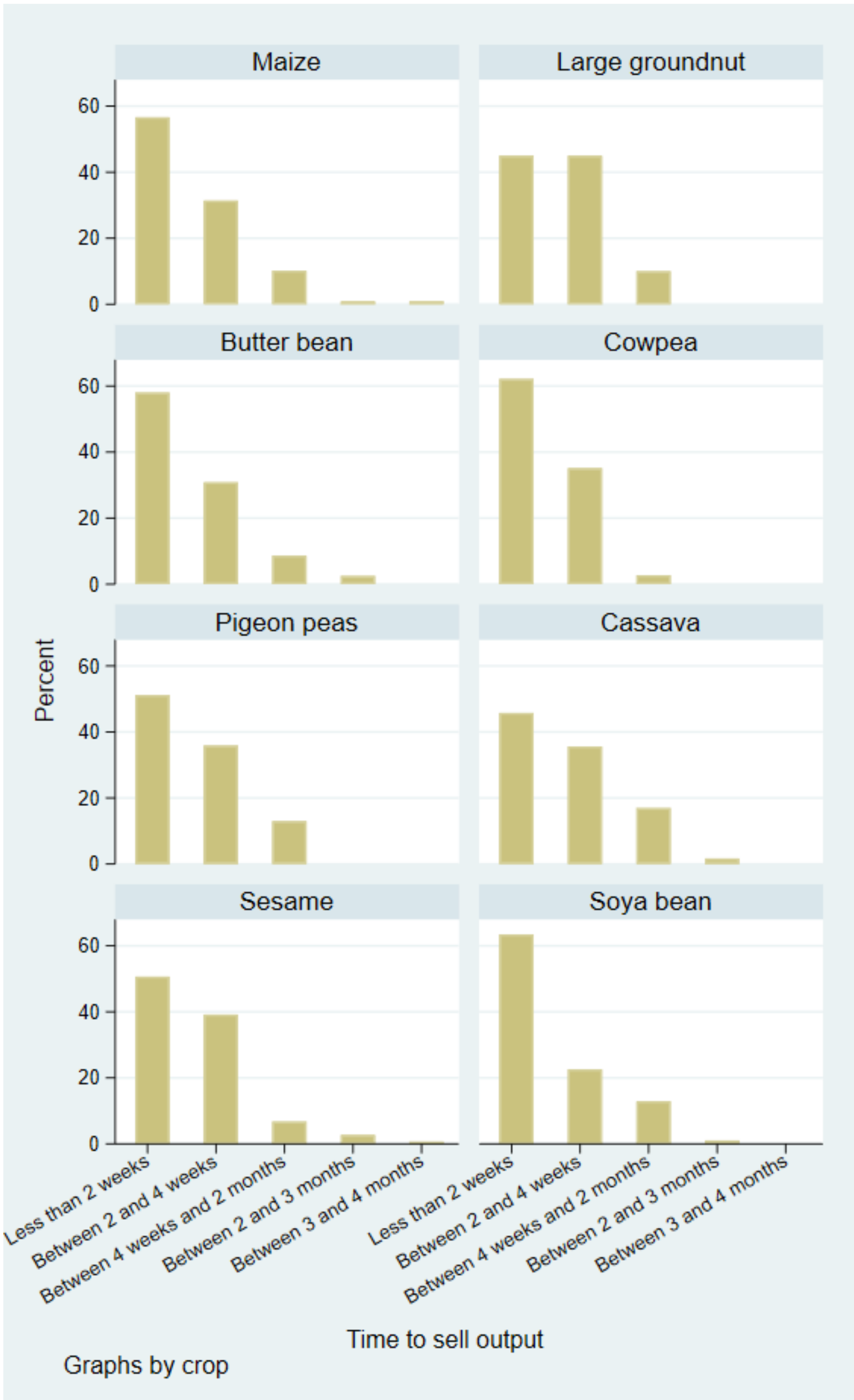

Figure 2: Histograms of time to sell crop by crop

Table 1: Summary Statistics

	Observations	Mean	Standard Deviation	Minimum	Maximum
Time to sell	835	3.465868	2.195968	2	16
Output	835	5.807589	1.319312	1.609438	9.740969
Price ratio	835	1.161046	.2912583	.1636233	2.083333
Poor storage	835	.7017964	.4577435	0	1
Financial constraints	835	.851497	.355811	0	1
Own consumption	835	.5760479	.4944791	0	1
Price information	835	.411976	.4924858	0	1
Crop concentration	835	.4092219	.1499209	.1712	1

Table 2: Average price ratio per crop and province

	Province				
Crop	Nampula	Zambezia	Manica	Sofala	Total
Maize	1.453	1.320	1.229	1.325	1.309
Nut	1.222	1.197	1.218	1.103	1.185
Bean	1.137	1.192	1.185	1.063	1.165
Cowpea	1.121	1.246	1.070	1.114	1.123
Pigeon pea	0.967	1.003	1.251	1.143	1.009
Cassava	1.096	0.959	1.219	0.878	1.062
Sesame	1.029	1.026	1.193	1.160	1.136
Soya	1.035	1.145	1.055	1.298	1.113
Total	1.153	1.130	1.200	1.154	1.161

Table 3: Correlation between explanatory variables

Variables	Exp. price growth	Output (log)	Poor storage	Liqui- dity c.	Own - cons.	Price info.	Place of sale	Crop conc.	Age (log)	Male Male	School- ing	High elast.	Exp. price	Actual price
Expected price growth	1.00													
Output (log)	0.11	1.00												
Poor storage	-0.14	-0.02	1.00											
Liquidity constrained	-0.02	0.04	0.07	1.00										
Own consumption	0.08	0.18	0.00	0.09	1.00									
Price information	-0.08	-0.02	0.09	-0.11	-0.12	1.00								
Place of sale	0.09	-0.11	0.13	-0.02	-0.12	0.21	1.00							
Crop concentration	0.05	0.09	-0.04	-0.06	0.09	0.06	-0.08	1.00						
Age (log)	0.02	0.01	-0.08	0.01	-0.06	0.05	0.06	0.03	1.00					
Male	-0.06	0.07	-0.00	-0.06	-0.05	0.03	-0.08	-0.05	-0.02	1.00				
Schooling	-0.03	0.08	0.02	0.02	0.08	0.06	-0.06	0.03	-0.45	0.22	1.00			
High elasticity	0.06	0.06	0.16	0.01	-0.12	0.26	0.06	0.01	0.06	-0.00	0.01	1.00		
Expected price	0.09	-0.46	-0.06	-0.06	-0.24	0.02	0.08	-0.08	0.10	0.01	-0.06	-0.03	1.00	
Actual price	-0.33	-0.47	-0.00	-0.06	-0.22	0.06	0.05	-0.11	0.09	0.02	-0.05	-0.05	0.86	1.00

Table 4: Time to Sell - Benchmark Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Expected price growth	0.378**	0.379**	0.464***	0.315**	0.342**	0.277*
	(0.0153)	(0.0123)	(0.0022)	(0.0395)	(0.0250)	(0.0695)
Output (log)	-0.143***			-0.159***	-0.157***	-0.147***
	(0.0040)			(0.0018)	(0.0018)	(0.0059)
Poor storage		-0.352**		-0.397***	-0.390***	-0.428***
		(0.0146)		(0.0045)	(0.0041)	(0.0013)
Liquidity constrained			-0.586***	-0.559***	-0.503***	-0.514***
			(0.0000)	(0.0000)	(0.0001)	(0.0001)
Constant	-1.233***	-2.001***	-1.899***	-0.343	-0.641	-0.549
	(0.0015)	(0.0000)	(0.0000)	(0.3893)	(0.1419)	(0.2557)
Observations	835	838	838	835	835	835
Crop FE	YES	YES	YES	YES	YES	YES
Province FE	NO	NO	NO	NO	YES	YES
Crop and province FE	NO	NO	NO	NO	NO	YES

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Time to Sell - Alternative explanations

	(1)	(2)	(3)	(4)	(5)
Expected price growth	0.298*	0.346**	0.275*	0.332**	0.286*
	(0.0532)	(0.0233)	(0.0759)	(0.0355)	(0.0736)
Output (log)	-0.158***	-0.151***	-0.151***	-0.156***	-0.174***
	(0.0019)	(0.0028)	(0.0034)	(0.0018)	(0.0010)
Poor storage	-0.401***	-0.426***	-0.417***	-0.395***	-0.368**
	(0.0040)	(0.0025)	(0.0032)	(0.0039)	(0.0109)
Liquidity constrained	-0.548***	-0.495***	-0.553***	-0.546***	-0.537***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Own consumption	-0.324**				
	(0.0368)				
Price information		0.854***			
		(0.0000)			
Place of sale			0.172		
			(0.1000)		
Crop concentration				0.562	
				(0.1331)	
Age (log)					0.342
					(0.1348)
Male					0.350*
					(0.0518)
Schooling					-0.061**
					(0.0256)
Constant	-0.029	-0.661	-0.395	-0.661	-1.596
	(0.9462)	(0.1013)	(0.3301)	(0.1482)	(0.1060)
Observations	835	835	835	835	835
Crop FE	YES	YES	YES	YES	YES
Province FE	NO	NO	NO	NO	NO
Crop and province FE	NO	NO	NO	NO	NO

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Time to Sell - Interactions with elasticity and liquidity constraints

	(1)	(2)	(3)	(4)	(5)	(6)
Expected price growth	0.013	-0.033	-0.052	0.577***	0.532***	0.532***
	(0.9503)	(0.8694)	(0.8020)	(0.0011)	(0.0049)	(0.0087)
High elasticity	-0.882**	-1.030***	-1.004***	1.158*	1.074	1.037
	(0.0201)	(0.0054)	(0.0064)	(0.0735)	(0.1057)	(0.1283)
Expected price growth x elasticity	0.535*	0.663**	0.639**	-0.866	-0.779	-0.736
	(0.0624)	(0.0174)	(0.0239)	(0.1228)	(0.1769)	(0.2109)
Output (log)	-0.141***	-0.140***	-0.132**	-0.131***	-0.130***	-0.123**
	(0.0044)	(0.0045)	(0.0125)	(0.0078)	(0.0082)	(0.0182)
Poor storage	-0.391***	-0.387***	-0.418***	-0.391***	-0.387***	-0.422***
	(0.0049)	(0.0041)	(0.0015)	(0.0048)	(0.0040)	(0.0013)
Liquidity constrained	-0.535***	-0.474***	-0.476***	0.553	0.640	0.680
	(0.0000)	(0.0002)	(0.0005)	(0.1848)	(0.1331)	(0.1288)
Liquidity constrained				-0.705**	-0.716**	-0.737**
x expected price growth				(0.0170)	(0.0181)	(0.0211)
Liquidity constrained x elasticity				-2.385***	-2.470***	-2.412***
				(0.0019)	(0.0016)	(0.0022)
Liquidity constrained x elasticity				1.630**	1.685**	1.614**
x expected price growth				(0.0114)	(0.0105)	(0.0154)
Constant	-0.029	-0.273	-0.249	-0.978**	-1.243**	-1.249**
	(0.9443)	(0.5511)	(0.6136)	(0.0317)	(0.0120)	(0.0196)
Observations	835	838	838	835	835	835
Crop FE	YES	YES	YES	YES	YES	YES
Province FE	NO	NO	NO	NO	YES	YES
Crop and province FE	NO	NO	NO	NO	NO	YES

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Time to Sell - Source of effect

	(1)	(2)	(3)	(4)	(5)	(6)
Expected price	0.002	0.001	0.000	-0.002	-0.003	-0.004
	(0.6738)	(0.7804)	(0.9693)	(0.6468)	(0.5365)	(0.3800)
Expected price x elasticity				0.009*	0.009*	0.010*
				(0.0855)	(0.0565)	(0.0555)
Actual price	-0.009*	-0.010**	-0.008*	-0.010**	-0.011***	-0.010**
	(0.0554)	(0.0319)	(0.0772)	(0.0200)	(0.0099)	(0.0253)
Output (log)	-0.170***	-0.169***	-0.152***	-0.162***	-0.164***	-0.147***
	(0.0009)	(0.0009)	(0.0046)	(0.0014)	(0.0012)	(0.0058)
Poor storage	-0.421***	-0.416***	-0.443***	-0.406***	-0.401***	-0.431***
	(0.0021)	(0.0017)	(0.0007)	(0.0026)	(0.0022)	(0.0009)
Liquidity constrained	-0.551***	-0.494***	-0.506***	-0.528***	-0.469***	-0.479***
	(0.0000)	(0.0001)	(0.0002)	(0.0000)	(0.0004)	(0.0005)
Elasticity				-0.562***	-0.588***	-0.592***
				(0.0035)	(0.0018)	(0.0018)
Constant	0.263	0.035	0.023	0.490	0.265	0.308
	(0.4968)	(0.9324)	(0.9580)	(0.2127)	(0.5280)	(0.4887)
Observations	835	835	835	835	835	835
Crop FE	YES	YES	YES	YES	YES	YES
Province FE	NO	YES	YES	NO	YES	YES
Crop and province FE	NO	NO	YES	NO	NO	YES

Robust pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A1: Variable definitions

Time to sell	Time (in weeks) it took to sell share of crop destined for sale.
Actual price	Price at which crops were sold (in Mozambican meticais by kilo)
Expected price	Expected price by farmer 30 days after the interview (in Mozambican meticais by kilo)
Expected price growth	Ratio of expected price to actual price
Output (log)	Total crop output in kilos (in logs)
Poor storage	Dummy taking value 1 if farmer reports storage conditions as either fair or poor.
Liquidity constrained	Dummy taking value 1 if farmer did not buy seeds.
Own consumption	Dummy taking value 1 if most of crop is destined for sale.
Price information	Dummy taking value 1 if farmer gets information on prices at least once a week.
Place of sale	Dummy taking value 1 if most crop is sold at tenement
Crop concentration	Hirschman-Herfindahl index of share of total cultivated surface of each crop. A higher value means higher dependence on fewer crops.
Age (log)	Age (in logs) of the head of household
Male	Dummy taking value 1 if head of household is male
Schooling	Number of years of schooling of the head of household