Wait and Sell: Farmers' individual preferences and crop storage in Burkina Faso

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Abstract

This paper investigates the reasons why African farmers who face similar financial constraints and agro-ecological conditions differ in storage behavior. We argue that even in cases when farmers are unconstrained and benefit from facilitated access to granaries, we can establish a causal link between discount rate and storage in a framework where agents are still time-consistent. We first provide a simple onfarm storage model which shows mechanisms at stake when taking into account both risk and time preferences. We then test the model's predictions using original data on agricultural decisions, collected from 1500 farmers in two regions of Burkina Faso, who were also asked hypothetical risk aversion and time discounting questions. We provide a identification strategy which tackles the issue of self-selection in market participation. We find a statistically significant impact of risk and time preferences on storage behavior for unconstrained farmers. Our results are robust to various measures of risk and time preferences. This paper presents one of the first set of field evidence that links risk aversion and time discounting to observed agricultural decisions.

Key words: storage, discount rate, risk aversion, agriculture.
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1 Introduction

Many developing countries experience significant seasonal price variability of food staple products (see Coleman 1991 and Barrett 2007). In West-African countries, grain prices such as millet, maize and sorgho typically decline in August-September, reflecting increased supplies from ongoing harvests. For example, in rural markets in Burkina Faso where our study takes place, we observe that millet prices decreased by more than 30 percent between August 2012 and December 2012, which is close to what Aker (2008) reports for millet prices in Niger, where the average intra-seasonal price difference was 44 percent in the 2000s.

Such large seasonal fluctuations in food staple prices offer substantial inter-temporal arbitrage opportunities. Yet many farmers appear not to take advantage of it as they would be expected to do through storage. As often documented in the literature, farmers often sell their output at low prices post-harvest and buy similar commodities several months later at prices that are far higher than those received post-harvest (Stephens and Barrett 2011). This so-called "sell low, buy high puzzle" has been studied in a number of recent papers that examine the role of liquidity constraints in farmers' storage decisions. Barrett (2007) suggests that, if farmers have no other means to address temporary liquidity constraints, they might find it optimal to convert non-cash wealth in the form of grains into cash, even knowing that they will need to buy back grain later at a higher price. Stephens and Barrett (2011) moreover show that credit indeed seems to influence crop sales and purchase behaviors in the case of Kenya. Basu and Wong (2012) report results from a randomized experiment of food storage and food credit programs run in East Indonesia, which both increase economic well-being substantially. All these works are in line with the most obvious explanation of the "sell low, buy high puzzle", which is that many farmers are financially constrained and that only those who have marketable surplus (and an appropriate storage technology) are able to take advantage of price increases. In this paper, we focus on observed heterogeneity in storage behavior among unconstrained farmers, namely those who are able to generate a marketable surplus. The fact that farmers facing similar financial constraints and agro-ecological conditions differ in storage behavior is an additional puzzle to be solved and suggests that differences in agricultural decisions may also be explained by individual preferences. This research question is directly linked to a central issue in development policies: should we provide African farmers with storage equipments? Typically, if farmers are too impatient to store, they may be reluctant to use development tools like new storage technologies.

Standard practice in inter-temporal welfare analyses is to assume that risk and time preferences are the same across farmers, when one would expect a priori that subjective time preferences differ across different individuals (see Harrison et al. 2010). For that reason, recent papers from the field experiment literature aim at eliciting the value of risk aversion coefficients and discount rates for individuals. Harrison et al. (2002) elicit individual discount rates from a nationally representative sample of 268 Danish people. Using a sample of 253 Danish people as well, Andersen et al. (2008) make a joint elicitation of both discount rates and risk aversion coefficients, such approach providing lower estimates of discount rates compared to previous studies. Focusing on developing countries, Harrison et al. (2010) use data collected from risky choice experiments in Ethiopia, India and Uganda. Tanaka et al. (2010) collect data from sample of 160 Vietnamese villagers and show that people living in wealthy villages are not only less risk averse but also more patient.

In addition to field experiments set ups to elicit farmers' individual preferences, a small number of studies asses the extend to which individual preferences drive agricultural decisions (Ashraf et al. 2006, Bauer et al. 2012, and Dupas and Robinson 2013). Those three studies have in common to show, through randomized control trials, that present-bias may explain individuals' choices of adopting saving or credit innovations provided. All of them conjecture from their results that time-inconsistency might be an important constraint for saving, whether at home or in a "self-help group" with microcredit purpose. Related to those works focused on saving, the question we aim to tackle here is whether individual preferences drive another crucial agricultural decision, that is, storage. We argue that, even in cases when farmers are not financially constrained and benefit from facilitated access to granaries, we can establish a causal link between discount rate and storage in a framework where farmers are still time-consistent.

We provide a simple onfarm storage model that shows mechanisms at stake when taking into account both risk and time preferences. We then test the predictions of the model, using original data on agricultural decisions, collected from 1500 farmers in two regions of Burkina Faso, who were also asked hypothetical risk aversion and time discounting questions. We provide an identification strategy which tackles the issue of self-selection in market participation. We find a statistically significant impact of risk and time preferences on storage behavior of unconstrained farmers. Our results are robust to various measures of risk and time preferences. The paper is organized as follows: the theoretical model is presented in Section 2; the identification strategy is discussed in Section 3; the data used in the paper are presented in Section 4; results of estimations and robustness checks are presented in Section 5 and Section 6 concludes.

2 A simple onfarm storage model

In this section, we lay out a brief motivating framework for interpreting the main results. It is a two-period model where the first period refers to the harvest season while the second period refers to the lean season. At the harvest season, the farmer harvests a quantity H of grain. He consumes a quantity c_h^g of grain at the harvest season (home consumption) and a quantity c_h^m of a generic good bought in the market. The price of grain at the harvest season is $\underline{p}$. Let us denote s the quantity of grain that the farmer stocks from the harvest season to the lean season. At the lean season, the farmer consumes his stock. He consumes a quantity c_l^g of grain at the harvest season (home consumption) and a quantity c_l^m of the generic good. The price of grain at the harvest season is $\overline{p}$.

The per period utility function of the farmer is assumed to be constant relative risk aversion and of the following specific form (see Park 2006):

$$u\left(c^g, c^m\right) = \frac{\left(c^g \left(c^m\right)^\sigma\right)^{1-r}}{1-r},$$

where $\sigma > 0$ determines expenditure shares for grain and the marketed good and r is the constant relative risk aversion.

As the price of grain increases from the harvest to the lean season and the price of the generic good does not, the farmer only sells grain at the time he wishes consume the generic good bought in the market. In other words, the farmer has no incentives to store the generic good. Let us denote v_h^g and v_l^g, the quantity of grain sold by the farmer at the harvest and at the lean season, respectively. Hence, we have $v_h^g = c_h^m / \underline{p}$ and $v_l^g = c_l^m / \overline{p}$.

The budget constraint of the farmer, at the harvest season, is given by:

$$c_h^g + v_h^g + s = H, \tag{1}$$

and, at the lean season, his budget constraint is given by:

$$c_l^g + v_l^g = s. \tag{2}$$

Let $\rho = \frac{1}{1+\delta}$, where ρ is the discount factor and δ is the discount rate. The farmer chooses c_h^g, v_h^g, s, c_l^g and v_l^g that maximize

$$\overline{EU} = \frac{\left(c_h^g \left(\underline{p} v_h^g\right)^\sigma\right)^{1-r}}{1-r} + \rho \frac{\left(c_l^g \left(\overline{p} v_l^g\right)^\sigma\right)^{1-r}}{1-r}, \tag{3}$$

such that (1) and (2) hold.

Let us rescale the expected utility of the farmer and define $EU = \frac{\overline{EU}}{\underline{p}^{\sigma(1-r)}}$. The optimal values of c_h^g, v_h^g, s, c_l^g and v_l^g maximize

$$EU = \frac{\left(c_h^g \left(v_h^g\right)^\sigma\right)^{1-r}}{1-r} + \widetilde{\rho} \frac{\left(c_l^g \left(v_l^g\right)^\sigma\right)^{1-r}}{1-r}, \tag{4}$$

where $\widetilde{\rho} = \rho \left(\overline{p} / \underline{p}\right)^{\sigma(1-r)}$ is the *effective discount rate*, and such that (1) and (2) hold.

2.1 Optimal consumption and stock decision

Before going further, notice that the form of the utility function implies that the optimal consumption of each good (grain and generic good) is always strictly positive. Moreover, the consumption of grain in the lean season is strictly positive only if the level of stock is strictly positive. We can then show that the optimal consumption choice is as follows:

Proposition 1: *The farmer sells grain in the following way:*

$$v_h^{g*} = \frac{\sigma}{1+\sigma}\frac{1}{1+\widetilde{\rho}^{1/\widetilde{r}}}H \text{ and } v_l^{g*} = \frac{\sigma}{1+\sigma}\frac{\widetilde{\rho}^{1/\widetilde{r}}}{1+\widetilde{\rho}^{1/\widetilde{r}}}H,$$

and his consumption of grain is such that

$$c_h^{g*} = \frac{1}{1+\sigma}\frac{1}{1+\widetilde{\rho}^{1/\widetilde{r}}}H \text{ and } c_l^{g*} = \frac{1}{1+\sigma}\frac{\widetilde{\rho}^{1/\widetilde{r}}}{1+\widetilde{\rho}^{1/\widetilde{r}}}H,$$

and the total quantity of grain stored is

$$s^* = \frac{\widetilde{\rho}^{1/\widetilde{r}}}{1+\widetilde{\rho}^{1/\widetilde{r}}}H,$$

where $\widetilde{\rho} = \rho\left(\overline{p}/\underline{p}\right)^{\sigma(1-r)}$ *is the effective discount rate and* $\widetilde{r} = 1-(1+\sigma)(1-r)$ *is the effective relative risk aversion.*

Proofs are relegated to Appendix A.

2.2 Individual preferences and farmer's optimal decision

Now let us focus on the effect of individual preferences (time preference and risk aversion) affect the farmer optimal choice. We can show that the discount factor has the following effect:

Proposition 2: [Discounting] *The three following claims hold if and only if* $r \geq \frac{\sigma}{1+\sigma}$*: an increase in the discount rate,* δ*, (i) increases the quantity of grain sold at the harvest season, (ii) decreases the quantity of grain sold at the lean season, (ii) increases home consumption at the harvest season and increases home consumption at the lean season, and (iv) decreases total grain storage.*

Similarly, we can show that risk aversion has the following effect:

Proposition 3: [Risk Aversion] *The following claim holds if and only if the farmer is sufficiently patient and risk averse, i.e.* $r > \frac{\sigma}{1+\sigma}$ *and* $\rho \geq \left(\underline{p}/\overline{p}\right)^{\sigma/(1+\sigma)}$*, or sufficiently impatient and not risk averse, i.e.* $r < \frac{\sigma}{1+\sigma}$ *and* $\rho \leq \left(\underline{p}/\overline{p}\right)^{\sigma/(1+\sigma)}$*, an increase in risk aversion (i) decreases the quantity of grain sold at the harvest season, (ii) increases the quantity of grain sold at the lean season, (iii) decreases home consumption at the harvest season and increases home consumption at the lean season, and (iv) increases total grain storage.*

Contrary to Saha and Stroud (1994) who show that it is rational for risk-averse farmers to store grain for food security reasons, the model indicates that the effect of risk aversion on storage depends on time preferences. In particular, risk aversion is likely to decrease storage among patient farmers. Ignoring impatience, one would believe that farmers do not store because they love risk while they are actually both very risk averse and very patient.Assuming that σ is common to all the farmers, a linear approximation of s_i^* is (we introduce subscript i in order to designate farmer i):

$$s_i^* \simeq \beta_0 + \beta_1 r_i + \beta_2 \delta_i + \beta_3 H_i \tag{5}$$

In the empirical part of the paper, we provide an empirical strategy to estimate β_1 and β_2.

However, we do not observe the stock directly. Rather, we observe the quantities of grain sold by the farmers at the harvest season (v_{hi}^{g*}). From Proposition 1, we know that

$$v_{hi}^{g*} = \frac{\sigma}{1+\sigma}\left(1 - s_i^*\right),$$

and then a linear approximation of the level of sales is:

$$v_{hi}^{g*} = \gamma_0 + \gamma_1 r_i + \gamma_2 \delta_i + \gamma_3 H_i$$

with $\gamma_k = -\frac{\sigma}{1+\sigma}\beta_k$, for $k = 0, 1, 2, 3$.

2.3 Constrained farmers

In order to capture the fact that some farmers sometimes do not sale grains, we include the possibility that some degree of unobserved heterogeneity affect the observed levels of sales. Assume that there is an idiosyncratic shock ε that (negatively) affects both the level of sales at the harvest season and the level of sales at the lean season. This shock may be positive or negative and it is such that:

$$v_h^{g*} = \begin{cases} 0 \text{ if } \varepsilon \geq \frac{\sigma}{1+\sigma}\frac{1}{1+\tilde{\rho}^{1/\tilde{r}}}H \\ \frac{\sigma}{1+\sigma}\frac{1}{1+\tilde{\rho}^{1/\tilde{r}}}H - \varepsilon \text{ else} \end{cases} \text{ and } v_l^{g*} = \begin{cases} 0 \text{ if } \varepsilon \geq \frac{\sigma}{1+\sigma}\frac{\tilde{\rho}^{1/\tilde{r}}}{1+\tilde{\rho}^{1/\tilde{r}}}H \\ \frac{\sigma}{1+\sigma}\frac{\tilde{\rho}^{1/\tilde{r}}}{1+\tilde{\rho}^{1/\tilde{r}}}H - \varepsilon \text{ else} \end{cases}$$

In other words, if a sufficiently negative shock arises, then the level of sales may fall to zero.

In the rest of the paper, we focus on the level of sales at the harvest season. We call "constrained farmer", a farmer who sells no grain at the harvest season and "unconstrained farmer", a farmer who sells some grain at the harvest season.

Assume that ε is distributed according the cumulative distribution G, then the probability that the farmer's level sales is strictly positive is:

$$\Pr\left(v_h^{g*} > 0\right) = G\left(\frac{\sigma}{1+\sigma}\frac{1}{1+\tilde{\rho}^{1/\tilde{r}}}H\right).$$

We can show that individual preferences affect this probability in the following way:

Proposition 4: [Probability to sell at the harvest season] *(i) An increase in the discount rate, δ, decreases the probability to sold some grain at the harvest season, $\Pr\left(v_h^{g*} > 0\right)$, if and only if $r \geq \frac{\sigma}{1+\sigma}$. (ii) An increase in risk aversion increases the probability to sold some grain at the harvest season, $\Pr\left(v_h^{g*} > 0\right)$, if and only if the farmer is sufficiently impatient and risk averse, i.e. $r > \frac{\sigma}{1+\sigma}$ and $\rho \leq \left(\underline{p}/\overline{p}\right)^{\sigma/(1+\sigma)}$, or sufficiently patient and not risk averse, i.e. $r < \frac{\sigma}{1+\sigma}$ and $\rho \geq \left(\underline{p}/\overline{p}\right)^{\sigma/(1+\sigma)}$.*

2.4 Predictions

In the empirical part of the paper, we focus on unconstrained farmers, taking into account the fact that they may differ from constrained farmers (we tackle a selection problem). Our results (Propositions 2 (i) and 3 (i)) provide predictions on the sign of the effect of individual preferences on the level of sales at the harvest season for the subset of unconstrained farmers. Our results also provide predictions on the sign of the effect of individual preferences on the probability to belong to the group of unconstrained farmers (see Proposition 4). Our predictions depend on how the unconstrained farmers group differ from the constrained farmers group term of preferences. They also depend on the price ratio of grain, $\underline{p}/\overline{p}$, and on parameter σ.

Let δ^{nc} be the average discount rate of unconstrained farmers and δ^{w} be the average discount factor of the whole population of farmers. Similarly, let r^{nc} be the average constant relative risk aversion of unconstrained farmers and r^{w} be the average constant relative risk aversion of the whole population of farmers. Assume that the effect of individual preferences for the average farmer approximates the effect of preferences for his group (unconstrained/whole population).

All our empirical results are consistent with our theoretical predictions, in the following context:

Proposition 5: *If all the farmers are sufficiently risk averse and the farmers of the unconstrained group are more patient than the average farmer ($\frac{\sigma}{1+\sigma} < r^{nc}$ and $\frac{\sigma}{1+\sigma} < r^{w}$ and $\rho^{w} \leq \left(\underline{p}/\overline{p}\right)^{\sigma/(1+\sigma)} \leq \rho^{nc}$), then, (i) the effect of δ on the unconstrained farmer sales at the harvest season is negative whereas the effect of r is positive, and, (ii) the effect of δ on the probability that the farmer sells some grain at the harvest season is positive whereas the effect of r is negative.*

We will show in the empirical part that the distribution of farmers' preferences fits with this situation.[1]

3 Identification strategy

In this section, we estimate the effect of individual preferences on the sales of the farmer at the harvest season. The empirical model to be estimated is:

$$v_{hi}^{g*} = \gamma_0 + \gamma_1 r_i + \gamma_2 \delta_i + \gamma_3 H_i + \gamma_4 F_i + \epsilon_i$$

with $\gamma_1 = -\beta_1$, $\gamma_2 = -\beta_2$, $\gamma_3 = 1 - \beta_3$ and $\epsilon_i \sim N(0, \sigma_\epsilon)$. F_i is family size, an additional control variable. The empirical model to be estimated then becomes:

$$v_{hi}^{g} = \gamma_0 + \gamma_1 r_i + \gamma_2 \delta_i + \gamma_3 H_i + + \gamma_4 F_i + \varepsilon_i \tag{6}$$

where we assume $\varepsilon_i \sim N(0, \sigma_\varepsilon)$.

[1] TO BE DONE

This model obviously suffers from a sample selection bias. Sample selection bias arises in that the population of farmers whose behavior is modeled here, consists only of farmers who make sales and that these farmers differ in unmeasured ways from farmers who do not sell, i.e. $\mathrm{corr}(X_i, \varepsilon_i) \neq 0$ with $X_i = (r_i, \rho_i, H_i, F_i)$. Thus, we want to estimate Eq.(6) but data are missing on v_h^{g*} because we do not observe v_h^{g*} for constrained farmers. Some farmers indeed have $v_{hi}^{g*} = 0$ not because they chose to store all their maize (net of the harvest season self-consumption) but because their unobserved characteristics (e.g. managerial ability). This problem is in all respects similar to the standard selection problem, where one who wants to estimate the effect of education on women's wages has to deal with a missing data issue, women who do not to work having virtually a zero wage. We thus turn to a sample selection model to describe our estimation problem:

$$V_i = Z_i \beta + u_i \tag{7}$$

Eq.(7) says whether unit i participates in the market or not, i.e. $V_i = 1$ if $v_{hi}^{g*} > 0$ and $V_i = 0$ otherwise. In practice, we construct V_i such that $P(V_i = 1) = P(v_{hi}^{g*} > 0)$, which means that units who do not sell in period 1 do not sell in period 2 either. Vector Z_i includes r_i, ρ_i, H_i and F_i, among other regressors. We assume $u_i \sim N(0, \sigma_u)$ and $\mathrm{corr}(u_i, Z_i) = 0$.

In our framework, the population regression function for Eq.(6) is:

$$E(v_{hi}^{g*} | X_i) = X_i \gamma$$

where $X_i = (r_i, \rho_i, H_i, F_i)$, while the regression function for the subsample of non-null v_{hi}^{g*} is:

$$E(v_{hi}^{g*} | X_i, V_i = 1) = X_i \gamma + E(\epsilon_i | V_i = 1).$$

Selection bias problem arises because $E(\epsilon_i | V_i = 1) = E(\epsilon_i | u_i > -Z_i \beta) \neq 0$. We indeed have $\mathrm{corr}(\varepsilon_i, u_i) \neq 0$, notably because of our assumption that constrained and unconstrained farmers systematically differ in unobservable characteristics. There is thus an omitted variable in Eq.(6) correlated with X_i. Applying OLS to Eq.(6) would thus yield biased estimates of γ. The easiest way to estimate a model with sample selection is to use the bivariate normal model, in which case the selection equation (7) becomes the usual Probit model. There are two approaches to estimating the sample selection model under the bivariate normality assumption: the two-step procedure of Heckman (1979) and the maximum likelihood estimation. In this paper we use both.

Heckman estimator consists in estimating $\lambda(Z_i \beta, \theta)$ in:

$$I_{V_i=1}[v_{hi}^{g*}] = E(v_{hi}^{g*} | V_i = 1) + \nu_i = X_i \gamma + \lambda(Z_i \beta, \theta) + \nu_i.$$

The selection equation becomes the usual Probit model:

$$P(V_i = 1) = P(Z_i \beta + u_i > 0) = P(u_i < Z_i \beta) = \phi(Z_i \beta)$$

We estimate β, then compute the inverse Mills ratio and get $\widehat{\lambda}$. Afterward, we include $\widehat{\lambda}$ in Eq.(6)

and get consistent γ using OLS. We need an instrument to estimate (6)-(7). We use a dummy variable, V_2, which takes on value 1 if i made sale in period 2 during the previous season and zero elsewhere. This deserves further comments. We discussed this in next section.

Although Heckman approach provides a useful way to explore the problem, the model can also be estimated by the full maximum likelihood estimation (MLE), which requires the same level of restrictive assumptions on u_i and ε and is more efficient if u_i and ε are indeed jointly normally distributed. We thus apply MLE to our data as well.

4 Data

4.1 Sampling

The survey design generated a representative sample of farmers in two administrative districts of Burkina Faso, Tuy and Mouhoun provinces. Those provinces are located in the west region of the country, which is the main maize production area. Data were collected in January 2013 in cooperation with the Confédération Paysanne du Faso (CPF), a nation-wide producer organization. A total number of 77 villages were randomly selected from the CPF list. In those villages, an average number of 20 households were randomly selected as well. With the help of the Burkinabe Agriculture Ministry, twenty investigators and two supervisors were recruited. A total number of 1549 farmers were surveyed between January 21, 2013 and February 7, 2013. Surveys were conducted in Dioula language. The survey included an experimental section aimed at eliciting risk and time preferences and a household survey part aimed at characterizing households and farming decisions. We interviewed the household head, defined as the person responsible for farming decisions.

4.2 Household survey

The household survey a recall survey about what happen between January and December 2012. It is made of nine distinct sections: (i) socio-economic characteristics of the household and of the household's head; (ii) household's economic assets; (iii) crop production; (iv) crop sales; (v) fertilizer expenses: (vi) non agricultural activities undertaken by the household members; (vii) household's social expenses; (viii) household's loans and (ix) household's food expenses. Table 1 reports mean values for various farmer characteristics. On average, surveyed households have thirteen members, seven being working with farming activities. In our sample, 30% of households are equipped with latrines and with sheet metal roof in 70% of cases. Households hold an average of 5 bikes, 1 motorbike and 2 heads of draft cattle. In the majority of the cases, the household is headed by a man, who is 43 years old on average, has received a written education in 40% of cases and is very often member of a farmer organization (85% of cases), whatsoever CPF or another organization. In the regions were surveys were conducted, main crops are cotton, maize, sorghum, millet and sesame. Millet and sorghum are traditionally consumed, while maize and sesame are sold as well. This is reflected in the average sown areas and in the production levels in the sample.

Table 1: Sample characteristics

Household's characteristics	unit	Obs.	mean	std. dev.
family size	number	1549	12.7	8.8
labor force	number	1549	7.1	5.4
latrine	yes=1, no=0	1549	0.32	0.46
roof quality	yes=1, no=0	1549	0.69	0.46
bike	number	1549	4.9	4.2
motorbike	number	1549	0.95	1.13
draft cattle	number	1549	2.4	2.54
sex	yes=male	1549	0.98	0.13
age	years	1549	42.9	12.7
education	yes=1, no=0	1549	0.39	0.49
producer organization	yes=1, no=0	1549	0.85	0.35
Cultivated areas				
cotton	ha	1549	3.95	4.61
maize	ha	1549	2.06	3.28
sorghum	ha	1549	1.84	2.2
millet	ha	1549	0.89	1.55
sesame	ha	1549	0.5	1.07
Production levels				
cotton	kg	1543	4454	10867
maize	kg	1545	3624	7100
sorghum	kg	1546	1340	1953
millet	kg	1547	544	1002
sesame	kg	1540	105	262

Since data were collected in January 2013, we do not observe the quantity of maize sold in period 2 over the studied crop season (2012-2013) but we do observe the quantity of maize sold in period 2 over previous season. Table 2 summarizes information on both current v_{hi}^{g*}, the quantity of maize sold between October 2012 and January 2013, and previous v_{li}^{g*}, the quantity of maize sold between January 2012 and September 2012. One half of the sample never sells. One third of the sample sells in period 1 and sometimes also in period 2. Some 15% do not sell in period 1 but do sell in period 2; such units do not exist in our theoretical framework.

Table 2: Sample of constrained and unconstrained farmers in terms of maize sales

	current $v_h^{g*} = 0$	current $v_h^{g*} > 0$	total
previous $v_l^{g*} = 0$	796	257	1053
previous $v_l^{g*} > 0$	230	241	471
total	1026	498	1524

"Current v_h^{g*}" refers to maize sales that occur between October 2012 and January 2013 while "Previous v_l^{g*}" refers to maize sales that occur between January 2012 and September 2012.

4.3 Eliciting Risk and Time Preferences

In order to elicit farmers' risk and time preferences, we use an artefactual field experiment in the terminology of Harrison and List (2004) . We asked hypothetical risk aversion and time discounting questions.

4.3.1 Risk aversion

Our experiments were built on the risk aversion experiments of Holt and Laury (2002) . We used a multiple price list design to measure individual risk preferences. We ran two experiments offering successively low and high payoffs. In each experiment, each participant was presented a choice between two lotteries of risky and safe options, and this choice was repeated nine times with different pairs of lotteries, as illustrated in Table 3 in the case of low pay-offs. Farmers were asked to choose either lottery A or lottery B at each game (a game is a row in the table). The first row of Table 3 indicates that lottery A offers a 10% probability of receiving 1000 FCFA and a 90% probability of receiving 800 FCFA, while lottery B offers a 10% probability of a 1925 FCFA payoff and a 90% probability of 50 FCFA payoff.

Low payoffs were chosen because they fitted previous experiments of Holt and Laury (2002) and Andersen et al. (2008) and because they amount to approximately one day income for a non skilled worker in Burkina Faso (around 1000 FCFA a day, ie 2 USD a day). In the second experiment, farmers were asked to choose between lotteries with 10 times higher payoffs. The offered payoffs were corresponding to an important amount of money, 10000 FCFA (around 20 USD) corresponding to the average price of one bag of 100 kg cereal after harvest or to

Table 3: The paired lottery-choice decisions with low payoffs

	lottery A				lottery B					
	prob 1	gain 1	prob 2	gain 2	prob 3	gain 3	prob 4	gain 4	range of r	
1	0.1	1000	0.9	800	0.1	1925	0.9	50	$-\infty$	-1.71
2	0.2	1000	0.8	800	0.2	1925	0.8	50	-1.71	-0.95
3	0.3	1000	0.7	800	0.3	1925	0.7	50	-0.95	-0.49
4	0.4	1000	0.6	800	0.4	1925	0.6	50	-0.49	-0.14
5	0.5	1000	0.5	800	0.5	1925	0.5	50	-0.14	0.15
6	0.6	1000	0.4	800	0.6	1925	0.4	50	0.15	0.41
7	0.7	1000	0.3	800	0.7	1925	0.3	50	0.41	0.68
8	0.8	1000	0.2	800	0.8	1925	0.2	50	0.68	0.97
9	0.9	1000	0.1	800	0.9	1925	0.1	50	0.97	1.37
10	1	1000	0	800	1	1925	0	50	1.37	$+\infty$

Note: Last column was not shown to respondents.

10 days income for a non skilled worker.

In practice, lotteries A and B were materialized by two bags containing 10 balls of different colors (green for 1000 FCFA, blue for 800 FCFA, black for 1920 FCFA and transparent for 50 FCFA). The composition of the bags was revealed to the farmers but they had to choose between picking a ball in bag A or bag B without seeing the balls (blind draw). As indicated in last column of Table 3, neutral risk adverse individuals (r around zero) are expected to switch from lottery A to lottery B at row 5, while risk loving individuals ($r < 0$) are expected to switch to lottery B before row 5 and risk adverse individuals ($r > 0$) are expected to switch to lottery B after row 5.

We assume a utility function of the following form:

$$U(x) = x^{1-r}/(1-r)$$

where x is the lottery prize and r is the parameter to be estimated and denotes risk aversion. Expected utility is the probability weighted utility of each outcome in each row. A farmer is indifferent between lottery A, with associated probability p_A to earn a and probability $1-p_A$ to earn b, and lottery B, with probability p_B to earn c and probability $1-p_B$ to earn d, if and only if his expected utility is the same in both lotteries:

$$p_A.U(a) + (1-p_A).U(b) = p_B.U(c) + (1-p_B).U(d)$$

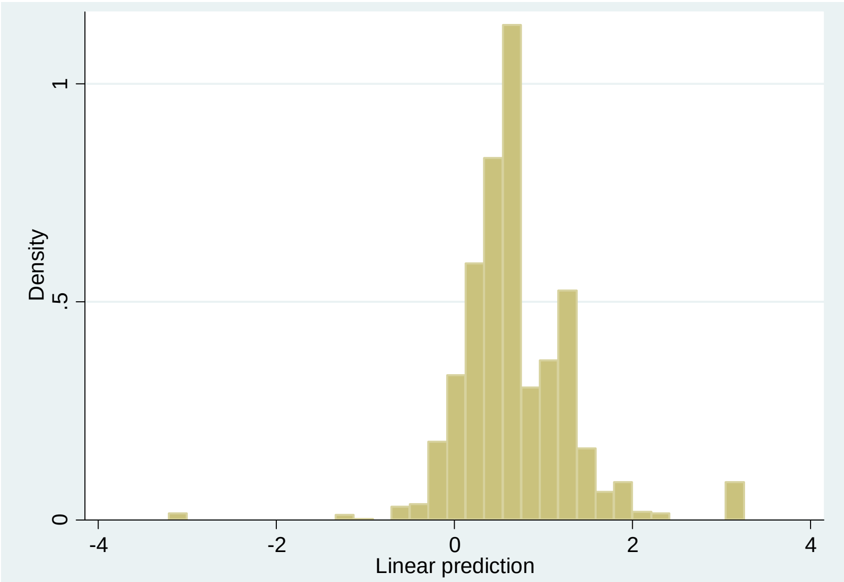
Assuming a CRRA utility function,

$$p_A.\frac{a^{1-r}}{1-r} + (1-p_A)\frac{b^{1-r}}{1-r} = p_B.\frac{c^{1-r}}{1-r} + (1-p_B)\frac{d^{1-r}}{1-r}$$

which can be solved numerically in term of r.

Just as in Holt and Laury (2002) and Andersen et al. (2008), we allow risk aversion to be a linear function of the observed households' characteristics. We consider six characteristics that we assumed unambiguously exogenous in driving risk preferences: gender, age, family size, education, village, province. Estimated individual r coefficients are predicted values of the model, which we estimate using an interval regression (tobit model). Figure1 displays the distribution of the risk coefficients predicted from the low-payoff experiment. Results show that a minority of farmers exhibit a risk loving or risk neutrality behavior. Most of the farmers are risk adverse, with an average of $r = 0.6$ in the low-payoff experiment and $r = 0.5$ in the high-payoff experiment. This is in line with previous findings suggesting that farmers' preference for risk is quite low Binswanger and Sillers (1983) . Those average values are comparable to the ones obtained by Harrison et al. (2010) for India, Ethiopia and Uganda using similar experiments.

Figure 1: Estimated risk aversion coefficients (low payoffs)



4.3.2 Discount Rate

To our knowledge, there is no study that aims to elicit discount rates in developing countries. We thus built our time preference experiment on works of Harrison et al. (2002) and of Coller and Williams (1999) . However we had to adapt the content in order to present pay-offs that make sense to the respondents. To do so, we ran pre-tests of the experiment from a subset of farmers before the survey. We used two experiments to elicit farmers' time preferences, those experiments differing in the time delays offered to the farmers. In the first experiment, farmers were invited to choose between receiving a given amount in one day time (option A) or receiving a bigger amount in five-days time (option B), and this choice had been repeated nine times, with different payoffs. The amount of payment A corresponds to the average price of one bag of 100 kg of cereals after harvest. Table 4 displays the experiment aiming to elicit this discount rate that we call current discount rate hereafter. The first row of Table 4 indicates that farmer had to choose between receiving 10,000 FCFA tomorrow or 10,400 FCFA in five days.

In a second experiment, farmers were invited to choose between receiving a given amount in one month-time (option A) or receiving a bigger amount in two-months time (option B), and

Table 4: “Would you prefer to get A in one day or B in five days?”

	A	B
1	10000	10400
2	10000	10700
3	10000	11000
4	10000	11500
5	10000	12000
6	10000	13000
7	10000	14000
8	10000	17000
9	10000	20000

Table 5: “Would you prefer to get A in one month or B in two months?”

	A	B	range of δ	
1	10000	12000	0	0.06
2	10000	15000	0.06	0.13
3	10000	18000	0.13	0.19
4	10000	20000	0.19	0.23
5	10000	23000	0.23	0.28
6	10000	29000	0.28	0.38
7	10000	48000	0.38	0.60
8	10000	75000	0.60	0.83

this choice being repeated eight times, with different payoffs. Table 5 displays the experiment aiming to elicit this discount rate that we call future discount rate hereafter.

An agent is indifferent between receiving payment M_t at time t or payment M_{t+1} at time $t+1$ if and only if:

$$U(w+M_t)+\frac{1}{1+\delta}U(w)=U(w)+\frac{1}{1+\delta}U(w+M_{t+1})$$

where w is his background consumption and δ accounts for the discount rate which is the parameter to be estimated. Assuming again a CRRA utility function and assuming no background consumption, this writes:

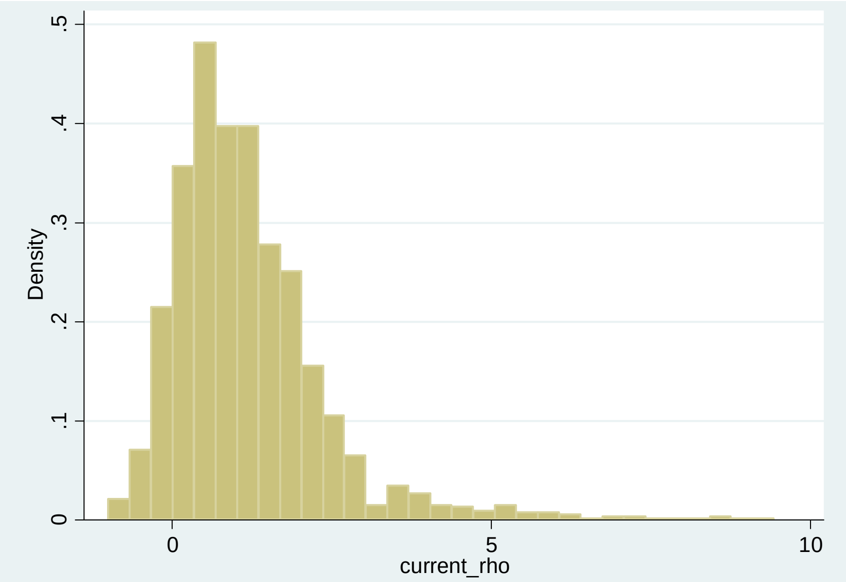
$$\frac{M_t^{1-r}}{1-r}=\frac{1}{1+\delta}\frac{M_{t+1}^{1-r}}{1-r},$$

from which we get δ as a function of risk aversion r:

$$\delta=\left[\frac{M_{t+1}}{M_t}\right]^{1-r}-1$$

Here again we allow δ to be a linear function of exogenous covariates. Estimated individual δ coefficients are predicted values of the model that we also use in order to elicit individual r, which we estimate again using an interval regression. Figure2 displays the estimated current discount rates. Table 6 reports mean values for farmer preferences considering the whole sample.

Figure 2: Estimated discount rates (5 days delay)



Focusing on the comparison of constrained farmers (those who do not sell maize at the harvest season) with unconstrained ones (those who sell maize at the harvest season), data show that they differ in many observable dimensions - which is in line with our assumption that they may also differ in terms of unobservable characteristics. In particular, farmers who do not sell maize (constrained group) have smaller maize area and smaller harvested quantities (Table 7). They are also less risk averse and more impatient on average than those from the unconstrained group (Table 8).

Table 6: Farmers' preferences (whole sample)

	Obs	Mean	Std. Dev.	Min	Max
r (low payoffs)	1524	0.69	0.63	-3.21	3.25
r (high payoffs)	1524	0.64	0.73	-3.06	4.14
δ (late)	1524	0.24	0.25	-0.60	1.03
δ (near)	1524	1.20	1.25	-1.00	9.44

Table 7: Characteristics of constrained and unconstrained farmers

	$v_{hi}^{g*} = 0$	$v_{hi}^{g*} > 0$
n	1026	498
V_2 (yes/no)	0.22	0.48
H (kg)	2084	6894
v_{hi}^{g*} (kg)	0	1405
Maize area (ha)	1.24	3.77
Family size (nb)	12	13

Table 8: Farmers' preferences (constrained and unconstrained groups)

	Obs	Mean	Std. Dev.	Min	Max
		Constrained group			
r (low payoffs)	1025	0.61	0.63	-3.18	3.25
r (high payoffs)	1025	0.55	0.73	-3.00	4.14
δ (late)	1025	0.28	0.24	-0.60	1.03
δ (near)	1025	1.40	1.33	-1.00	9.44
		Unconstrained group			
r (low payoffs)	499	0.87	0.61	-3.21	3.22
r (high payoffs)	499	0.81	0.71	-3.06	3.95
δ (late)	499	0.15	0.23	-0.60	0.99
δ (near)	499	0.80	0.93	-1.00	5.62

5 Results

Main results are presented in Table 9. Column (1) displays the results we get applying the Heckman two-step procedure to our data, while Columns (2) to (5) display the results we get applying the MLE. Comparing Column (1) and Column (2), we show that both estimators provide very similar results. Since the predicted values for preferences are generated from a prior regression, we employ bootstrap techniques Efron and Tibshirani (1993) to obtain standard errors that explicitly take into account the presence of generated regressors Pagan (1984) . We moreover report standard errors that are clustered at the village level.

Overall, the results appear very stable. Both risk and time preference appear to affect storage decision at standard levels of significance, with the expected sign. Risk aversion appear to decrease decision to sale in period 1, regardless of the variable used, i.e. risk aversion predicted from low payoff game or from high payoff game. In the case of time preference, results show that the size of coefficients varies with the variable used: impatience predicted from the one-month-delay game appears to have larger impact than impatience predicted from the 5-day-delay game.

Results are robust to various measures of risk and time preferences. Table 10 displays results we get when taking into account background consumption in calculations of risk and time preferences. Columns (6)-(7) present results obtained when using harvest value as proxy for background consumption, while Columns (8)-(9) present results obtained when using the value of sales in period 1.

6 Conclusion

This paper investigates the reasons why African farmers who face similar financial constraints and agro-ecological conditions differ in storage behavior. We argue that even in cases when farmers are unconstrained and benefit from facilitated access to granaries, we can establish a causal link between discount rate and storage in a framework where agents are still time-consistent. We first provide a simple onfarm storage model which shows mechanisms at stake

Table 9: Heckman two-step & ML estimates

	H2S		ML		ML		ML		ML	
Eq.(6)	(1)		(2)		(3)		(4)		(5)	
r	-409.2214	**	-366.0132	**	-412.5524	**	-296.9829	*	-339.0098	*
	(170.1073)		(186.2367)		(204.647)		(165.9452)		(182.4517)	
δ	**1350**	***	**1238.962**	**	**262.4242**	**	**1281.861**	**	**273.8874**	*
	(468.4)		(574.0178)		(128.8676)		(128.8676)		(141.0598)	
H	0.0796	***	0.1044	***	0.1034	***	0.1031	***	0.1020	***
	(0.0173)		(0.0262)		(0.0256)		(0.0263)		(0.0260)	
F	38.3109	***	31.5356	***	28.5459	**	30.2310	**	26.9680	**
	(11.4727)		(12.19)		(12.5421)		(12.0784)		(12.5303)	
cons	1974.264	***	1655.718	***	1702.381	***	1593.33	***	1635.977	***
	(545.9755)		(557.4609)		(567.2432)		(545.2844)		(554.9869)	
λ	-1600.295	***	-1390.06	***	-1386.328	***	-1382.506	***	-1379.517	***
	(475.0003)		(526.7386)		(525.8176)		(540.7769)		(543.1386)	
Eq.(7)										
r	0.3733	***	0.3668	***	0.4219	***	0.3013	***	0.3544	***
	(0.0583)		(0.1243)		(0.1280)		(0.1105)		(0.1113)	
δ	-1.0496	***	-0.9956	**	-0.2769	***	-1.0341	***	-0.2879	***
	(0.1560)		(0.3961)		(0.929)		(0.3979)		(0.0944)	
H	0.0000	***	0.0001	***	0.0001	***	0.0001	***	0.0001	***
	(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)	
F	-.0158	***	-0.0154	**	-0.0120		-0.0141	*	-0.0104	
	(.0048)		(0.0077)		(0.0076)		(0.0081)		(0.0080)	
V_2	0.4064	***	0.2485	*	0.2468	*	0.2539	*	0.2518	*
	(0.0801)		(0.1320)		(0.1334)		(0.1331)		(0.1341)	
cons	-0.6062	***	-0.6502	***	-0.6479	***	-0.5978	***	-0.5930	***
	(.0828)		(0.1877)		(0.1839)		(0.1831)		(0.1792)	
Payoffs	low		low		low		high		high	
Time delay	late		late		near		late		near	

Table 10: Heckman two-step & ML estimates - Robustness check

	MLE		MLE		MLE		MLE	
Eq.(6)	(6)		(7)		(8)		(9)	
r	-99.8837		-246.6198	*	-298.2118	*	-258.9125	*
	(93.8478)		(147.9718)		(171.0354)		(153.6742)	
δ	1198.781	*	1422.484	**	1314.937	**	1346.058	**
	(680.4397)		(775.1814)		(690.7368)		(730.6142)	
H	0.1086	***	0.1100	***	0.1105	***	0.1090	***
	(0.0287)		(0.0293)		(0.0291)		(0.0287)	
F	30.6968	***	29.2199	**	28.2828	**	27.3472	**
	(12.7619)		(12.4742)		(12.7706)		(12.6200)	
cons	1621.216	***	1746.089	***	1640.148	***	1574.742	***
	(610.7394)		(644.2401)		(576.7407)		(561.4789)	
λ	-1241.689	***	-1277.883	***	-1296.313	***	-1274.088	***
	(528.5999)		(538.6033)		(513.9934)		((528.6766)	
Eq.(7)								
r	0.2108		0.2983	***	0.3933	***	0.3183	***
	(0.1302)		(0.0894)		(0.1012)		(0.0941)	
δ	-1.3137	***	-1.5327	***	-1.4593	***	-1.5000	***
	(0.3274)		(0.3702)		(0.3565)		(0.3607)	
H	0.0001	**	0.0001	**	0.0001	**	0.0001	**
	(0.0000)		(0.0000)		(0.0000)		(0.0000)	
F	-0.0129	*	-0.0127	***	-0.0114		-0.0107	
	(0.0075)		(0.0076)		(0.0073)		(0.0078)	
V_2	0.1927	*	0.2035	*	0.2058	*	0.2198	*
	(0.1140)		(0.1142)		(0.1675)		(0.1181)	
cons	-0.8014	***	-0.7903	***	-0.8	***	-0.6156	***
	(0.2012)		(0.1571)		(0.1675)		(0.1638)	
Payoffs	low		high		low		high	
Time delay	late		late		late		late	
Background consump.	Harvest value		Harvest Value		Sale Value		Sale Value	

when taking into account both risk and time preferences. We then test the model's predictions using original data on agricultural decisions, collected from 1500 farmers in two regions of Burkina Faso, who were also asked hypothetical questions in order to elicit their levels of risk aversion and time discounting. We provide an identification strategy which tackles the issue of self-selection in market participation.

We find a statistically significant impact of risk and time preferences on storage behavior for unconstrained farmers. Our results are robust to various measures of risk and time preferences. Overall, the results appear very stable. Both risk and time preference appear to affect storage decision at standard levels of significance, with the expected sign. Results are robust to various measures of risk and time preferences.

Appendix A: Proofs

Proof of Proposition 1: Assume that $c_h^g, v_h^g, c_l^g, v_l^g, s > 0$. The Lagrangian of the farmer's optimization problem is given by

$$L = EU + \mu_h \left(H - c_h^g - v_h^g - s\right) + \mu_l \left(s - c_l^g - v_l^g\right), \tag{8}$$

such that $\mu_h, \mu_l \geq 0$, and $\mu_h \left(H - c_h^g - v_h^g - s\right) \geq 0$, and $\mu_l \left(s - c_l^g - v_l^g\right) \geq 0$, and (1) and (2). The first order conditions include:

$$\frac{\partial L}{\partial c_h^g} = \left(c_h^g\right)^{-r} \left(v_h^g\right)^{\sigma(1-r)} - \mu_h = 0, \tag{9}$$

$$\frac{\partial L}{\partial v_h^g} = \sigma \left(c_h^g\right)^{1-r} \left(v_h^g\right)^{\sigma(1-r)-1} - \mu_h = 0, \tag{10}$$

$$\frac{\partial L}{\partial c_l^g} = \tilde{\rho} \left(c_l^g\right)^{-r} \left(v_l^g\right)^{\sigma(1-r)} - \mu_l = 0, \tag{11}$$

$$\frac{\partial L}{\partial v_l^g} = \tilde{\rho}\sigma \left(c_l^g\right)^{1-r} \left(v_l^g\right)^{\sigma(1-r)-1} - \mu_l = 0, \tag{12}$$

$$\frac{\partial L}{\partial s} = -\mu_h + \mu_l = 0, \tag{13}$$

and (1) and (2). Solving these system of equation leads to positive values $c_h^g, v_h^g, c_l^g, v_l^g, s > 0$. This proves the result.□

Proof of Propositions 2 to 4: Notice that $\tilde{r} \geq 0$ is equivalent to $r \geq \frac{\sigma}{1+\sigma}$. The results follow.□

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