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Linking risk aversion, time preference and fertilizer use in Burkina Faso

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Abstract

This paper investigates whether Burkinabe maize farmers' fertilizer-use decisions are correlated with their risk and time preferences. We conducted a survey and a series of hypothetical experiments on a sample of 1,500 farmers. We find that more patient farmers do use more fertilizer, but it is only because they plant more maize (a fertilizer-intensive crop) rather than because they use more fertilizer per hectare of maize planted. Conversely, we find no statistically significant link between risk aversion and fertilizer use. We use a simple two-period model, which suggests that risk aversion may indeed have an ambiguous effect on fertilizer use.

Keywords: Fertilizer, Risk aversion, Time preferences, Burkina Faso

Résumé

Ce papier analyse la relation entre les décisions d'utilisation d'engrais des producteurs de maïs au Burkina Faso et les caractéristiques de ces producteurs en termes d'impatience et d'aversion au risque. 1500 producteurs ont été enquêtés sur leurs activités agricoles et ont participé à un dispositif expérimental basé sur des paiements hypothétiques. Notre principal résultat est sur la relation entre l'impatience et l'utilisation d'engrais : nous établissons que les producteurs les plus patients utilisent davantage d'engrais, et plantent davantage de maïs, qui est une plante qui requiert de l'engrais, sans pour autant intensifier leur production de maïs. Nous ne trouvons pas de relation significative entre l'aversion au risque et l'utilisation d'engrais.

Mots-clés : Engrais, Aversion au risqué, Impatience, Burkina Faso

JEL: D13, D14, D91, O12

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1 Introduction

Many agricultural experts argue that low fertilizer use is a key reason for Africa's insufficient food production and food insecurity (Sanchez, 2002). In recent years, Asia underwent a green revolution, i.e. major gains in agricultural productivity explained by the use of fertilizers and other modern inputs, while agricultural yields and fertilizer use have remained very low in Africa (Morris *et al.*, 2007; Evenson & Gollin, 2003). Yet, recent trials in Kenya and Burkina Faso suggest that, when fertilizer is used at the recommended dose, the yield increases it generates make it a profitable investment (Duflo *et al.*, 2008, 2011).[1] Given these promising results, why some farmers still use small amounts of fertilizer on their land is particularly puzzling.

In the literature, there has been extensive discussion on the determinants of the adoption of technology in agriculture, focusing on missing or imperfect markets for credit, insurance and land (Binswanger & Sillers, 1983; Dercon & Christiaensen, 2011; Karlan *et al.*, 2014), lack of knowledge and education (Foster & Rosenzweig, 1995; Lambrecht *et al.*, 2014), some behavioral constraints (Duflo *et al.*, 2011), heterogeneous returns (Suri, 2011), and insecure property rights (Jacoby *et al.*, 2002). While risk and time preferences have been recognized as being theoretically linked to technology adoption,[2] empirical evidence for a link between farmers' risk preferences and technology adoption is much more scarce (Knight *et al.*, 2003; Liu, 2013; Liu & Huang, 2013) and to our knowledge, there is no empirical evidence for a link between time preferences and technology adoption in the literature.[3] This paper is one of the first to provide empirical evidence of the link between time preferences and farmers' decisions to use fertilizer.

[1] See Koussoubé & Nauges (2015) for the case of maize in Burkina Faso.

[2] See, among others, Feder (1980), Feder *et al.* (1985), Jacoby *et al.* (2002), Duflo *et al.* (2011), and Dercon & Christiaensen (2011).

[3] Knight *et al.* (2003) analyzed the adoption of technology by Ethiopian farmers. They established an empirical link between a measure of risk aversion and the adoption of innovation, a dichotomous variable that is set to one if farmers adopted at least one new input (fertilizer or pesticide) and one new crop. Liu (2013) examined the role of risk aversion in the decision to adopt genetically modified cotton in China and found that farmers who are more risk averse adopt genetically modified cotton later than farmers who are not. Conversely, Liu & Huang (2013) showed that risk aversion is positively correlated with pesticide use by Chinese farmers.

We study fertilizer use by maize farmers in two cotton producing regions in Burkina Faso where access to fertilizer and extension services is easy, i.e. the limited fixed costs of buying or learning to use fertilizer are not likely to be a major obstacle to fertilizer use. In this area, farmers typically buy fertilizer in May-June for maize and harvest their grain six months later. In 2013, in partnership with the Confédération Paysanne du Faso, a nation-wide farmers organization, we conducted a survey of farmers and a series of hypothetical experiments to estimate the individual risk and time preferences of a representative sample of 1,500 maize farmers.

We elicit farmers' risk and time attitudes using risk and time experiments with hypothetical payments. The payoffs used in the risk experiments were chosen because they were in line with results of previous experiments by Holt & Laury (2002) and Andersen *et al.* (2008). We built our time preference experiment based on Harrison *et al.* (2002) and on Coller & Williams (1999), but we adapted the content in order to offer hypothetical payoffs that were realistic to respondents, using the average price of a 100 kg bag of cereal as a reference value. The time discounting questions included both short-term trade-offs and future trade-offs.

In this paper, we match different measures of farmers' risk aversion and time preferences with different measures of fertilizer use. We capture the relationship between risk and time preferences and fertilizer use in a linear regression specification, which includes a range of observable individual characteristics and village-level effects. We find that the farmers who exhibit lower discount rates - whether in the short or the long term - purchase larger amounts of fertilizer for maize, but it is only because they plant more maize, which is a fertilizer-intensive crop, rather than because they use more fertilizer per hectare of maize planted. We find that a one-standard-deviation decrease in the discount rate is associated with a 6.5% to 26% increase in the total amount of fertilizer used, depending on the regression model and on the measure of time discounting used. Conversely, we find no statistically significant link between risk aversion and fertilizer use.

To provide an interpretation of the empirical results, we also present a simple expected utility two-period model of a risk-averse farmer who chooses whether or not to purchase fertilizer. In the model, the curvature of the instantaneous utility function captures both the farmer's risk aversion and his propensity to smooth consumption over time. The model shows that discounting time decreases fertilizer use, while risk aversion has an ambiguous effect on fertilizer use that depends on the farmer's discounting. Because fertilizer is a risk increasing technology, one might expect a negative relationship between risk aversion and fertilizer use.[4] However, the relationship between risk aversion and fertilizer use may be more complex than it seems. Indeed, the use of fertilizer requires an investment whose returns are delayed, which affects inter-temporal consumption arbitrage. Therefore, risk adverse farmers may want to use more fertilizer today in order to increase their future consumption, compared to risk neutral farmers, who are less concerned with inter-temporal smoothing. Since inter-temporal smoothing depends on impatience, the effect of risk aversion on fertilizer use is likely to depend on impatience too. More specifically, if the farmer is sufficiently patient, he is willing to sacrifice some consumption during the planting season in order to increase his consumption in the harvest season. In this case, an increase in risk aversion would tend to moderate the drop in consumption in the planting season (in order to smooth consumption over time) by decreasing investment in fertilizer. On the contrary, if the farmer is sufficiently impatient, he purchases a limited amount of fertilizer to ensure high consumption in the planting season. In this case, an increase in risk aversion would lead the farmer to increase fertilizer use in the planting season to avoid too low consumption in the harvest period. This simple two-period model suggests that risk aversion has two potential effects with the opposite sign on fertilizer use, which may explain why we do not find any statistically significant empirical evidence on the relationship between risk aversion and fertilizer use with our data. Our interpretation is suggestive, however, and needs to be confirmed by studies that establish causal links. The results are robust to controlling for a range of observable

[4] It is worth-mentioning that the effect of risk aversion on the adoption of innovation depends on the risk increasing or risk decreasing nature of the innovation itself. For example, the use of pesticides provides protection against production uncertainty, which implies a risk decreasing effect (Feder, 1979). Conversely, the use of fertilizer increases yield variability, which implies a risk increasing effect (Just & Pope, 1979).

individual characteristics and village-level effects. We cannot, however, rule out the possibility that the results arise from an unobserved factor affecting experimental measures of discounting as well as fertilizer use. We discuss this concern in the last section of the paper.

The rest of the paper is organized as follows. Section 2 provides some background information on maize production and fertilizer use in Burkina Faso and describes the survey and the data set. Section 3 describes the design and procedure of the risk and time experiments and a descriptive analysis of the risk and time preferences we elicited. Section 4 provides a description of the empirical framework and the results. Section 5 describes a stylized model of fertilizer use that provides intuition for our empirical results. We discuss causal inference in Section 6. Section 7 concludes the paper.

2 Survey data

2.1 Survey Procedure

The survey design generated a representative sample of households in two administrative districts of Burkina Faso, the Tuy and Mouhoun provinces. These provinces are located in the western region of the country, which is the main maize production area. Data were collected in cooperation with the Confédération Paysanne du Faso (CPF), a nation-wide farmers organization. A total of 73 villages were randomly selected from the CPF list (Figure 1). In these villages, an average of 20 households were selected through a door-to-door strategy with the aim of gathering a random sample of households. With the help of the Burkinabe Agriculture Ministry, 20 investigators and two supervisors were recruited for data collection. A total of 1,502 households were surveyed in February 2013. The survey includes data on purchases of fertilizer and harvesting of the maize crop between January 2012 and January 2013. The surveys were conducted in the Dioula language. The investigators interviewed the household head, defined here as the person responsible for farming decisions.[5] The participants were interviewed face-to-face and participated in various hypothetical risk and time experiments.

2.2 Data Description

Table 1 reports the mean values for the characteristics of the households. On average, surveyed households have 13 members, 7 of whom work in farming activities. In almost all cases, the household head is a man with an average age of 43 years, who received a formal education in 40% of cases, lives a 40-minute drive from the closest market.[6] The climate in the Tuy and Mouhoun provinces is characterized by abundant rainfall (around 800 mm per year) and a marked dry season, which is suitable for maize and cotton production. Other main crops are sorghum and millet. On average, the households surveyed own 10 hectares of land of which they devote about 2 hectares to maize, 3 hectares to sorghum and millet, and about 4 hectares to cotton.

Farmers use hybrid maize seeds that have been optimized for specific traits, such as yield, and are more sensitive to fertilizer application than other crops.[7] Consequently, farmers apply fertilizer on their maize fields rather than on their sorghum and millet fields. This is consistent with some evidence from other African countries for higher rates of input use on maize plots, even compared to plots planted with cash crops (Sheahan & Barrett, 2014). This is also consistent with the relatively high maize yields we observe in our data: mean yields in our sample are 1.5 tons per hectare for maize and only 0.8 t/ha for sorghum and 0.7 t/ha for millet.[8] The farmers we surveyed purchased about 230 kg of N-P-K fertilizer[9] for maize in 2012, which corresponds to an average of 110 kg per hectare of maize. It is worth mentioning that these farmers also use fertilizer for cotton. How-

[5] We remain agnostic concerning the way in which the individual preferences and beliefs are aggregated within each family.

[6] We calculated the distance between each village and its associated assembly market using Arcgis software. We assumed the speed of vehicles traveling on paved roads to be 40 km per hour and the speed on unpaved roads to be 10 km per hour.

[7] Yield increases thanks to nitrogen uptake are larger for maize than for sorghum and millet (Ciampitti *et al.*, 2014).

[8] National averages are 1.8 t/ha for maize, 1.1 t/ha for sorghum and 0.85 t/ha for millet (FAOSTAT, 2016).

[9] NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium.

ever, they do not have to buy fertilizers for cotton in the planting season because they obtain fertilizers on a credit provided by the Societé Burkinabé des Fibres et des Textiles (SOFITEX), the Burkinabé semi-public cotton company.[10]

3 Hypothetical Risk and Time Preference Data

The farmers in the survey were asked questions concerning both risky and intertemporal choices. We used hypothetical questions rather than incentivized ones to elicit farmers' risk and time preferences for two main reasons. Aside from the obvious motivation for using hypothetical surveys instead of incentivized scoring rules (i.e. it is cheaper and easier to administer to large samples), we also wished to avoid disturbing the operations of other activities run by the same project. Moreover, there is robust evidence that elicited risk preferences do not differ when they are inferred from hypothetical or from incentivized choices. Holt & Laury (2002) find similar distribution of constant relative risk aversion for hypothetical choices and incentivized choices and Vieider *et al.* (2015) show that incentivized measures and survey measures are correlated.

3.1 Design and Procedure of Experiments

Risk Choices: Our hypothetical questions were built on the risk aversion experiments conducted by Holt & Laury (2002). We designed a multiple price list 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 the choice was repeated nine times with different pairs of lotteries, as illustrated in Table 2. Farmers were asked to choose either lottery A or lottery B. For example, the first row of Table 2 indicates that lottery A offers a 10% probability of receiving 1,000 CFA and a 90% probability of receiving 800 CFA, while lottery B offers a 10% probability of a 1,925 CFA payoff and a 90% probability of 50 CFA payoff.

[10]The farmers who use this credit in the planting season reimburse the price of fertilizer when the cotton is harvested and they are paid for their cotton production by SOFITEX.

Low payoffs were chosen because they were in line with the ranges of relative risk aversion parameters used in previous experiments by Holt & Laury (2002) and Andersen *et al.* (2008), and because they amount to approximately one day's income for a non-skilled worker in Burkina Faso (around 1,000 CFA, i.e. about 2 USD a day in 2012), which seemed credible to respondents. In the second experiment, farmers were asked to choose between lotteries with ten times higher payoffs, 10,000 CFA (around 20 USD) corresponding to the average price of a 100-kg bag of cereal at harvest (Table 3).

In practice, lotteries A and B were materialized by two bags of 10 marbles of different color: green for 1000 CFA, blue for 800 CFA, black for 1925 CFA and transparent for 50 CFA. The farmers were told what was in the bags, but they could not see the contents. Assuming the CRRA utility function in equation 1, we deduce that, as indicated in the last column of Table 2, risk neutral individuals ($r = 0$) are expected to switch from lottery A to lottery B at row 5, risk loving individuals ($r < 0$) are expected to switch to lottery B before row 5, and risk averse individuals ($r > 0$) are expected to switch to lottery B after row 5.

Time Choices: We based our time hypothetical questions on Harrison *et al.* (2002) and on Coller & Williams (1999), who collected experimental data in Denmark and in the U.S., respectively. However, we had to adapt the content in order to offer hypothetical payoffs that made sense to the respondents. To do so, we ran pretests of the experiment with a subset of farmers in January 2013. We conducted two experiments that differed in the time delays offered to respondents. In the first experiment, farmers were invited to choose between receiving a given amount in one day's time (option A) or receiving a larger amount in five days' time (option B), and this choice was repeated nine times, with increasing payoffs, as option B. Table 4 shows the experiment aimed at eliciting the four-day delay discount rate. In the second experiment, farmers were invited to choose between receiving a given amount in one month's time (option A) or receiving a larger amount in two months' time (option B), and this choice was repeated eight times, with increasing payoffs as option B. Table 5 displays the experiment aiming to elicit the one month delay discount rate.

3.2 Estimation of Risk and Time Parameters

In order to make our results comparable with those of previous studies, we assume a constant relative risk aversion (CRRA) utility function of the following form:

$$U(w+x) = (w+x)^{1-r}/(1-r), \tag{1}$$

where w is the farmer's background consumption, x is the lottery prize and r is the parameter to be estimated and denotes the constant relative risk aversion of the individual. When the farmer faces a lottery with two outcomes a and b with corresponding probability p and $1-p$, we focus on his expected utility, which is given by $EU = pU(w+a) + (1-p)U(w+b)$.

We also assume that farmers have additively time separable preferences. An agent utility evaluated at time t from receiving payment g_t at time t and payment $g_{t+\Delta t}$ at time $t+\Delta t$ is given by:

$$U(w+g_t) + \rho\,(\Delta t)\,U(w+g_{t+\Delta t}) \tag{2}$$

where w is his background consumption, ρ accounts for the discount factor and Δt is the time interval between the two payments. We assume a constant discount rate, that is

$$\rho\,(\Delta t) = \left(\frac{1}{1+\delta}\right)^{\Delta t}, \tag{3}$$

where δ denotes the discount rate.

Interval Regression: We use the same approach as Andersen *et al.* (2008) to infer the parameters of the utility function. We allow risk aversion to be a linear function of the characteristics of the households in the survey. We consider five characteristics that we assume to be unambiguously exogenous in driving risk preferences: gender, age, education, province and village. We assume the CRRA utility function form in Equation 1 and that the background consumption is zero, $w = 0$. Let $r = \gamma + X'\theta + \epsilon$ be the model, where r represents the risk aversion coefficient, X is the vector of the observed characteristics of the farmer and ϵ follows normal law $N(0, \sigma^2)$. We know only that the unobserved r is in the interval $[\underline{r}, \overline{r}]$. We estimate the model using an interval regression, a generalization of censored regression for data where each observation is measured using the interval scale. The likelihood contribution of farmer i is the probability that his risk aversion belongs to the interval $[\underline{r}, \overline{r}]$: $\Pr(\underline{r}_i \leq r_i \leq \overline{r}_i)$.

We then obtain elicited individual r coefficients, which are predicted values conditional on observed characteristics X in the model:

$$\hat{r}_i = \hat{\gamma} + X_i'\hat{\theta}, \tag{4}$$

where $\hat{\gamma}$ and $\hat{\theta}$ are estimated parameters from the interval regression. In this way, two relative risk aversion estimates are obtained for each farmer, one from the low payoff risk experiment (Table 2) and one from the high payoff risk experiment (Table 3).

We use a similar procedure to estimate the individual discount rate parameters (one from the 4 day experiment and one from the one month experiment). We assume the CRRA utility function form in Equation 1 and that farmers have time separable preferences represented by the discounted utility as in Equation 2. We assume that the discount factor is defined as in Equation 3. We compute the interval that includes the discount rate corresponding to each switching point, assuming that the risk aversion parameter is $r = 0.7$, i.e. equals the average risk parameter from the low-payoff experiment and the high-payoff experiment (see Table 6), and that the background consumption is zero, $w = 0$ (see the last column in Table 4 and in Table 5).

As in the case of the risk aversion parameter, we obtain elicited individual discount rates, which are predicted values conditional on observed characteristics X in a linear model:

$$\hat{\delta}_i = \hat{\nu} + X_i'\hat{\mu}, \tag{5}$$

where $\hat{\nu}$ and $\hat{\mu}$ are estimated parameters from the interval regression. Two discount rate estimates are obtained for each farmer, one from the 4 day experiment (Table 4) and one from the one month experiment (Table 5).

Midpoint of Intervals: Another common approach used to approximate the parameters consists in using the midpoints of intervals (see, for instance, Andreoni and Sprenger 2012). We use the intervals computed for each switching point in each experiment (see the last column in Tables 2 to 5). The approximation of the preference parameter is the midpoint of the interval corresponding to the row in which the farmer switched from choice A to choice B.[11]

3.3 Descriptive Analysis of Risk and Time Parameters

Table 6 provides descriptive statistics for the different estimates of the risk aversion parameter. The results of the two experiments show that most farmers are risk averse. The low-payoff experiment showed that the average risk aversion parameter is $r = 0.37$ when considering the midpoint of intervals and $r = 0.7$ when using the interval regression method. The high-payoff experiment showed that the average risk aversion parameter is $r = 0.33$ when using the midpoint of intervals and $r = 0.64$ when using the interval regression method.

Although interval midpoints are often used in the experimental literature because they are easy to calculate, they mask some of the heterogeneity in individual responses. Using this raw measure requires assuming that people who always chose lottery A have a risk aversion coefficient of 1.37, while their response implies that their risk aversion coefficient could actually be much higher. Moreover it is worth mentioning that the average

[11] If the farmer always chose choice A, then the approximation of his parameter is the higher bound of the interval. If the farmer always chose choice B, then the approximation is the lower bound of the interval.

values obtained with the interval regression method are very close to those obtained by Harrison *et al.* (2010) who used similar experiments in India, Ethiopia, and Uganda.

Table 7 provides descriptive statistics for the estimates of the discount rate. In the one month delay experiment, we find that the average discount rate is $\delta = 0.32$ with the interval midpoint approach and $\delta = 0.23$ with the interval regression approach. In the four day experiment, we find that the average time discount rate is $\delta = 0.10$ with the interval midpoint approach and $\delta = 0.09$ with the interval regression approach. Overall, farmers appear to be very impatient with respect to the distant future, with an average value of 23 – 32 percent per month. Interestingly, they are even more impatient with respect to the near future, with an average value of 9 – 10 percent for each four day interval. Our estimates of the time preference parameter are well above previous estimates of discount rates that have been elicited for selected segments of populations in developed countries, which range from one to three percent per month (Harrison *et al.*, 2002). Our estimates also suggest that the farmers in our sample have higher discount rates than rural villagers who participated in the experiments conducted by Tanaka *et al.* (2010) in Vietnam and Bauer *et al.* (2012) in India. Taken together, these results suggest that Burkinabe farmers are, on average, more impatient than Vietnamese and Indian farmers, and that Vietnamese and Indian farmers are more impatient than a nationally representative sample of Danish people. This ranking makes sense since those with the least amount of wealth are expected to have the highest levels of impatience. Indeed, a very high discount rate characterizes life among farmers in a developing country like Burkina Faso: life expectancy is relatively short, and the likelihood of losing one's savings due to diseases and agricultural shocks can be quite high.[12]

[12]Our estimates of the discount rate differ considerably from those provided by Liebenehm & Waibel (2014), who conducted similar experiments with 211 households in Mali and Burkina Faso in 2007 and 2011. These authors report discount rates close to zero, meaning that households are extremely patient. This is a surprising result considering that poor people are usually expected to have high levels of impatience.

4 Econometric Framework and Results

4.1 Econometric Framework

We capture the relationship between risk and time preferences and fertilizer use in a linear regression specification, which includes a range of observable individual characteristics and village level effects:

$$\textit{Fertilizer Use}_i = \alpha + \beta \textit{Risk Pref}_i + \gamma \textit{Time Pref}_i + \mathbf{C_i'}\theta + \eta_v + \varepsilon_i, \tag{6}$$

where Fertilizer Use$_i$ is a measure of fertilizer use by farmer i, *Risk Pref*$_i$ is a measure of farmer i's risk aversion, and *Time Pref*$_i$ is a measure of farmer i's time preferences. $\mathbf{C_i'}$ is a set of farmer-specific control variables, which includes the total cultivated area, the number of plows, the number of cattle, the number of poultry, sex, age, education of the head of the household, labor force, distance to the market and province. η_v is a village dummy. Note that when the parameters using the elicited parameter approach were used, we do not use sex, age, education, province and village as controls because they are already included in the estimates of the risk and time preference parameters.

Fertilizer use: We use three different measures of fertilizer use. The first variable, called *Intensity*, refers to the quantity of N-P-K fertilizer purchased to grow maize (in kg) per hectare of maize owned. The second variable, called *Fertilizer*, refers to the quantity of N-P-K fertilizer purchased to grow maize (in kg). The last measure, called *Maize Area*, refers to the area of land under maize (in hectares). Since we use the total cultivated area as a control variable, the effect of risk and time preferences on the area under maize actually captures the effect of these preferences on the share of land that is devoted to maize.

Risk and Time Preferences: We use the two risk parameters obtained from the low and the high payoff experiments as well as the two time preference parameters obtained from the four day and the one month delay experiments. In each model, we use estimates we obtained from the interval midpoints and from the interval regression method successively.

4.2 Empirical Results

Fertilizer Use Intensity: Table 8 and 9 provide the estimates of the effects of risk aversion and time discounting on the intensity of fertilizer use (kg of NPK per hectare), when we use the midpoints of intervals and the parameters elicited from the interval regression as measures of preferences, respectively. Overall, we do not find any robust statistically significant link between risk aversion or time discounting and the intensity of fertilizer use.

Total Amount of Fertilizer: Table 10 and 11 provide the estimates of the effects of risk aversion and time discounting on the total amount of N-P-K fertilizer purchased (in kg), when we use the midpoints of intervals and the parameters elicited from the interval regression, respectively. Overall, the coefficient of time discounting is statistically significant and negative, whatever the regression model and the measure of time discounting used. A one standard deviation increase in the discount rate is associated with a decrease in the total amount of fertilizer purchased, ranging from 6.5% (when the midpoints of intervals are used as measures of time discounting) to 26% (when the parameters elicited from the interval regression are used as measures of time discounting). Conversely, the coefficient of risk aversion is much less stable and not significant in most estimates.

Maize Area: Table 12 and 13 provide the estimates when we use the midpoints of intervals and the elicited parameters as measures of farmers' preferences, respectively. Overall, the results are qualitatively very similar to those previously obtained for the total amount of N-P-K fertilizer purchased. The coefficient of time discounting on maize area is negative and almost always statistically significant. A one standard deviation increase in the discount rate results is associated with a decrease on the area planted to maize, ranging from 5% (when the midpoints of intervals are used as measures of time discounting) to 27% (when the parameters elicited from the interval regression are used as measures of time discounting). Conversely, the coefficient of risk aversion is not robustly significant.

5 A Simple Model of Fertilizer Use

In this section, we develop a two period stylized agricultural household model focusing on the role of risk and time preferences in determining fertilizer use.[13] The model provides the main intuitions behind the expected effects of the discount rate and of the risk aversion parameter on fertilizer use. Consider a two period model. The first period refers to the planting season (subscript p) and the second to the harvest season (subscript h). A household's indirect utility depends on consumption of a generic good with price one. The household has initial wealth B_0 and faces an agricultural production technology which is represented by a production function F. The quantity of fertilizer is denoted by x. The levels of inputs (such as land and labor) are given. Production is stochastic, i.e. F depends on a random variable, ξ, which represents unanticipated shocks on agricultural production (e.g. weather shocks). At planting, the household can either consume its wealth, c_p, or purchase fertilizer. The price of fertilizer is normalized to one. At harvest, the household consumes its agricultural production, c_h. For the sake of simplicity, we assume the household has no savings.[14]

The household chooses the quantity of fertilizer that maximizes its discounted utility. Its crop season optimization problem can be expressed as follows:

$$\text{Maximize}_{c_p,c_h,x}\, EU = \frac{1}{1-r}\left(c_p\right)^{1-r} + \frac{1}{1+\delta}\frac{1}{1-r}E\left(\left(c_h\right)^{1-r}\right) \tag{7}$$

[13] See Dercon & Christiaensen (2011) for a more general formulation of the dynamic decision problem.

[14] Consequently, the only way to increase consumption at harvest is to purchase more fertilizer in the planting season. This is obviously a caricature of possible options, but the goal of the model is to provide a simple explanation for the role of risk aversion in the farmer's decision to buy fertilizer. Introducing the possibility of saving would not alter the qualitative results.

s.t.

$$c_p + x \leq B_0 \text{ (planting season budget constraint),} \quad (8)$$

and,

$$c_h \leq F(x, \xi) \text{ (harvest season budget constraint).} \quad (9)$$

Utility is assumed to be time separable with constant relative risk aversion parameter. Preferences are fully described by two parameters: r, which measures the relative risk aversion and δ, which refers to the discount rate. E denotes the expectation operator. The production function, F, is assumed to be (strictly) increasing and concave with respect to the quantity of fertilizer used, $F_x > 0$ and $F_{xx} \leq 0$.[15]

We solve the household's utility maximization problem focusing on the optimal level of fertilizer use, x^* (Proofs are relegated to Appendix). We first show the following result:

Result 1 [Fertilizer use and impatience]: *The optimal quantity of fertilizer used always decreases with impatience:*

$$\frac{\partial x^*}{\partial \delta} < 0.$$

Patient households use more fertilizer than impatient households. This result is due to the time gap between the planting season and the harvest season.

Our second result focuses on the level of risk aversion of the household:

Result 2 [Fertilizer use and risk aversion]: *The optimal quantity of fertilizer used increases with risk aversion for sufficiently impatient households: there exists* $\tilde{\delta} \geq 0$ *such that*

$$\frac{\partial x^*}{\partial r} \geq 0 \Leftrightarrow \delta \geq \tilde{\delta}.$$

The intuition of Result 2 is as follows. If the household strongly discounts future utility, i.e. if $\delta \geq \tilde{\delta}$, it tends to choose a high level of consumption c_p and uses a small amount of

[15]Fertilizers increase the supply of nutrients in the soil. When the nutrient content of soils increases, yields typically increase at a decreasing rate. However, with sufficiently high levels of nutrient supplies, yields reach a plateau. With even higher nutrient supplies, the concentration of nutrients becomes toxic and yields decrease (IFA, 1992). Our assumption that F is increasing and concave is a reasonable assumption for farmers who do not make excessive use of fertilizers.

fertilizer in the planting season. However, the more risk averse the household, the smaller its consumption in the planting season because it seeks to smooth its consumption between the two seasons. To ensure sufficient consumption at harvest, it has to increase soil fertility by purchasing fertilizer. As a result, in that case, fertilizer use at the planting season increases with risk aversion. Conversely, if the household does not strongly discount future utility, i.e. $\delta \leq \tilde{\delta}$, it tends to use large quantities of fertilizer and choose a low consumption level in the planting season. However, the more risk averse the household, the less it uses fertilizers at the planting season, again because it seeks to smooth its consumption. In order to increase its consumption at the planting season, it must use less fertilizer. For this reason, in that case, fertilizer use decreases with risk aversion.

In both cases, risk aversion acts as a countervailing power of farmers' time preference: risk aversion increases fertilizer use among impatient farmers and decreases fertilizer use among patient farmers. Whether risk aversion increases or decreases fertilizer use thus remains an empirical issue.

In this paper, we did not find any significant empirical link between risk aversion and fertilizer use, either with midpoints of intervals or parameters elicited from the interval regressions. The results obtained from the model suggest that risk aversion can have either a positive or a negative effect on the total amount of fertilizer used for maize and on the proportion of land that is devoted to maize. This may explain why we did not find a robust empirical link between risk aversion and fertilizer used for maize and the share of land planted under maize.

6 Alternative Explanations

6.1 Time-inconsistency

The results of a recent study in Kenya, Duflo *et al.* (2011)suggested that farmers may not purchase fertilizer because they tend to be present biased. This time-inconsistency would push them to procrastinate, postponing fertilizer purchases until later periods, when they may be too impatient to purchase fertilizer. Under this assumption, there may be a relationship between farmers' time inconsistency and fertilizer use. We use our data to examine this relationship.

We follow Andersen *et al.* (2008) and Prelec (2004) in constructing a measure of present bias from the two time experiments available, assuming the following discount factor function:[16]

$$\rho(\Delta t) = e^{-\beta(\Delta t)^{\alpha}}, \tag{10}$$

where β denotes the discount rate and $0 \leq \alpha \leq 1$ and $-\alpha$ is a measure of "decreasing impatience". The instantaneous discount rate implied by this discount factor function is $\alpha\beta(\Delta t)^{\alpha-1}$ and it collapses to β as α goes to 1.

We solve Equation 10 for β and α. We obtain an estimate for the time discounting parameter, β, and the present bias parameter, α. Table 7 provides descriptive statistics for the estimated discount rate when the farmers are assumed to have hyperbolic preferences. The average values of $-\alpha$ obtained using the midpoints of intervals and the parameters elicited from the interval regression are similar. Most of the farmers have hyperbolic preferences, the average value of the present bias parameter (α) is $0.47-0.57$ and thus far below 1.

Table 15 and Table 16 provide the estimated relationship between the measure of present bias ($-\alpha$) and the total amount of fertilizer used for maize, using interval midpoints and the parameters elicited from the interval regression as measures of farmers' preferences, respectively. Table 17 and Table 18 provide the estimated relationship between the measure of present bias ($-\alpha$) and maize area, using interval midpoints and the parameters elicited from the interval regression as measures of farmers' preferences, respectively. Overall, the results are not conclusive. The coefficient of the present bias parameter does not appear to be stable and is not statistically significant in most estimates.

[16] We also used Laibson's quasi-hyperbolic preferences (Laibson, 1997). This does not qualitatively affect any of our results.

6.2 Complementary inputs

Another concern with our findings is that they arise from an unobserved complementary input that affects both our experimental measures of discounting and fertilizer use. The availability of complementary inputs, such as a labor force, can indeed affect the way farmers answer time-discounting questions as well as their decision to purchase and use fertilizer. A farmer in a household with a relatively high proportion of children or elderly family members is more likely to need cash, typically for health care, and consequently may seem to be impatient in the experiment. This farmer is also less likely to use fertilizer because he has less available labor on the farm.

We argue that none of the complementary inputs of fertilizer (labor and irrigation systems) is a good candidate to support this concern. Firstly, the labor force is always included as a control in all the regression models used. Secondly, the farmers in our survey have no access to irrigation, and rainfall shocks are likely to be captured by village and province dummies.

7 Conclusion

We analyzed the empirical link between individual risk and time preferences and the use of chemical fertilizers by maize farmers in Burkina Faso. We matched different measures of farmers' risk aversion and time preferences with different measures of fertilizer use. Our main result is that farmers who exhibit higher impatience devote a smaller proportion of their land to fertilizer-intensive crops - maize in our study - and purchase smaller amounts of fertilizer at planting. This suggests that time preferences may play an important role in fertilizer-use decisions.

This interpretation needs to be confirmed by studies that establish causal links. However, our findings may have important policy implications. They suggest that reducing the cost of fertilizer during the planting season could effectively foster agricultural productivity in Burkina Faso (Duflo *et al.*, 2011) simply because this would push impatient farmers to purchase more fertilizer at planting. This could be achieved by fertilizer subsidies distributed in the form of vouchers. Alternatively, it could be achieved with a mechanism that provides fertilizer in kind to farmers during the planting season and recovers the cost of the fertilizers at harvest by deducting it from the farmers' sales, a mechanism that already exists in the cotton sector.

Appendix

Proof of Result 1: The two budgets constraints, (8) and (9), are obviously binding. Hence, $c_p = B_0 - x$ and $c_h = F(x, \xi)$. A necessary condition for an interior solution is then

$$\left(B_0 - x^*\right)^{-r} = \frac{1}{1+\delta} E\left(F_x\left(x^*, \xi\right)\left(F\left(x^*, \xi\right)\right)^{-r}\right). \tag{11}$$

The right hand side decreases with respect to x^* and δ whereas the left hand side increases with x^* and does not depend on δ. We thus conclude that x^* always decreases with δ.□

Proof of Result 2: The first order condition (11) characterizes x^* as a function of r. Differentiating condition (11) with respect to r leads to (we do not write the arguments):

$$\begin{aligned} & r\left(B_0 - x^*\right)^{-r-1} \frac{\partial x^*}{\partial r} - \left(B_0 - x^*\right)^{-r} ln\left(B_0 - x^*\right) \\ = & \frac{1}{1+\delta} E\left(F_{xx} F^{-r} - r\left(F_x\right)^2 F^{-r-1}\right) \frac{\partial x^*}{\partial r} - \frac{1}{1+\delta} E\left(F_x F^{-r} ln(F)\right). \end{aligned}$$

Rearranging and using condition (11), we obtain:

$$\left(r\left(1+\delta\right)\left(B_0 - x^*\right)^{-r-1} + E\left(-F_{xx} F^{-r} + r\left(F_x\right)^2 F^{-r-1}\right)\right) \frac{\partial x^*}{\partial r} = E\left(F_x F^{-r} ln\left(\frac{B_0 - x^*}{F}\right)\right).$$

The first term on the left hand side is positive and the right hand side decreases with x. Thanks to Result 1, this is sufficient to finish the proof.□

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Tables and Figures

Table 1: Sample Characteristics

Characteristics	Unit	Obs.	Mean	Std. Dev.	Min.	Max.
Family size	number	1502	12.7	8.9	1	70
Labor force	number	1502	7.1	5.4	1	48
Sex	man=1	1502	1.0	0.1	0	1
Age	year	1502	42.8	12.7	14	90
Education	yes=1	1502	0.4	0.5	0	1
Province	Tuy=1	1502	0.4	0.5	0	1
Cattle (none)	yes=1	1502	0.2	0.4	0	1
Cattle (more than 10)	yes=1	1502	0.6	0.5	0	1
Cattle (less than 10)	yes=1	1502	0.2	0.4	0	1
Plows	number	1502	2.0	1.7	0	18
Poultry	number	1502	21.3	27.2	0	300
Distance to market	minutes	1497	40.1	25.4	0	122
Purchase of fertilizer for maize						
Total amount of NPK fertilizer	kg	1502	231.5	419.4	0	5800
NPK fertilizer intensity	kg/ha	1250	109.8	73.5	0	500
Cultivated areas						
Total	ha	1502	10.0	9.0	0	88.5
Maize	ha	1502	2.1	3.3	0	35
Sorghum	ha	1502	1.8	2.2	0	30
Millet	ha	1502	0.9	1.6	0	25
Cotton	ha	1502	4.0	4.6	0	45
Peanut	ha	1502	0.3	0.5	0	5.5
Rice	ha	1502	0.1	0.4	0	8
Production						
Maize	ton	1497	3687.4	7190.0	0	97500
Sorghum	ton	1499	1342.9	1970.5	0	26520
Millet	ton	1500	544.7	1006.6	0	14400
Cotton	ton	1497	4488.3	11018.1	0	272160
Peanut	ton	1488	188.7	417.5	0	5232
Rice	ton	1497	190.3	767.2	0	17280

Note: The table provides summary statistics for a set of variables. yes=1 means the variable is a dummy, Tuy=1 means that the province is the Tuy region when the variable equals 1 and the Mouhoun region when the variable equals 0. *NPK Use* is the quantity of fertilizer (in kg) used to grow maize. *Intensive Use* is the quantity of fertilizer (in kg) per hectare used to grow maize.

Table 2: The Paired Lottery-choice Decisions with Low Payoffs

	lottery A				lottery B				range of r	
	p	gain a	$1-p$	gain b	p	gain c	$1-p$	gain d		
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: The last column was not shown to the respondents. It provides the associated interval for the CRRA parameter using the CRRA utility specification (1). In lottery A, p is the probability to gain a and $1-p$ the probability to gain b. In lottery B, p is the probability to gain c and $1-p$ the probability to gain d.

Table 3: The Paired Lottery-choice Decisions with High Payoffs

	lottery A				lottery B				range of r	
	p	gain a	$1-p$	gain b	p	gain c	$1-p$	gain d		
1	0.1	10000	0.9	8000	0.1	19250	0.9	500	$-\infty$	-1.71
2	0.2	10000	0.8	8000	0.2	19250	0.8	500	-1.71	-0.95
3	0.3	10000	0.7	8000	0.3	19250	0.7	500	-0.95	-0.49
4	0.4	10000	0.6	8000	0.4	19250	0.6	500	-0.49	-0.14
5	0.5	10000	0.5	8000	0.5	19250	0.5	500	-0.14	0.15
6	0.6	10000	0.4	8000	0.6	19250	0.4	500	0.15	0.41
7	0.7	10000	0.3	8000	0.7	19250	0.3	500	0.41	0.68
8	0.8	10000	0.2	8000	0.8	19250	0.2	500	0.68	0.97
9	0.9	10000	0.1	8000	0.9	19250	0.1	500	0.97	1.37
10	1	10000	0	8000	1	19250	0	500	1.37	$+\infty$

Note: The last column was not shown to the respondents. It provides the associated interval for the CRRA parameter using the CRRA utility specification (1). p is the probability to gain a and $1-p$ the probability to gain b. In lottery B, p is the probability to gain c and $1-p$ the probability to gain d.

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

	A	B	range of δ	
1	10000	10400	0	0.016
2	10000	10700	0.016	0.027
3	10000	11000	0.027	0.039
4	10000	11500	0.039	0.057
5	10000	12000	0.057	0.076
6	10000	13000	0.076	0.111
7	10000	14000	0.111	0.144
8	10000	17000	0.144	0.236
9	10000	20000	0.236	0.320

Note: Column "range of δ" indicates the associated interval for monthly δ for a respondent who switches from A to B. We use the CRRA utility specification (1) and the expected utility model as in Eq. (2) with constant discount factor as in Eq. (3).

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

Note: Column "range of δ" indicates the associated interval for monthly δ for a respondent who switches from A to B. We use the CRRA utility specification (1) and the expected utility model as in Eq. (2) with constant discount factor as in Eq. (3) when the CRRA parameter is $r = 0.69$.

Table 6: Estimated Risk Preference Parameter

Parameter	Obs.	Estimation	Mean	Std. Dev.
Risk aversion (low-payoffs)	1502	Midpoint	0.37	1.06
Risk aversion (low-payoffs)	1502	Elicited	0.70	0.64
Risk aversion (high-payoffs)	1502	Midpoint	0.33	1.09
Risk aversion (high-payoffs)	1502	Elicited	0.64	0.73

Note: This table provides summary statistics for the estimated risk preferences.

Table 7: Estimated Time Preference Parameter (constant discount rate)

Parameter	Obs.	Estimation	Mean	Std. Dev.
Discount rate (1-month)	1502	Midpoint	0.32	0.31
Discount rate (1-month)	1502	Elicited	0.23	0.24
Discount rate (4-days)	1502	Midpoint	0.10	0.09
Discount rate (4-days)	1502	Elicited	0.09	0.10

Note: This table provides summary statistics for the estimated time preferences.

Table 8: Fertilizer Use Intensity and Risk and Time Preferences (midpoint of interval)

	[1]	[2]	[3]	[4]
	Intensity (kg/ha)	Intensity (kg/ha)	Intensity (kg/ha)	Intensity (kg/ha)
Risk aversion	1.72	3.43**	1.76	3.48**
	(1.91)	(1.71)	(7.9)	(1.73)
Discount rate	3.39	2.65	6.26	3.62
	(6.31)	(6.23)	(20.08)	(20.19)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1250	1250	1250	1250

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village dummies, total cultivated area, sex, age, education, labor force, province, number of plows, cattle and poultry.

Table 9: Fertilizer Use Intensity and Risk and Time Preferences (elicited parameter)

	[1] Intensity (kg/ha)	[2] Intensity (kg/ha)	[3] Intensity (kg/ha)	[4] Intensity (kg/ha)
Risk aversion	0.91	-1.92	1.52	-1.52
	(4.54)	(3.39)	(4.91)	(3.51)
Discount rate	-1.71	-0.25	-16.39	-10.39
	(13.4)	(13.95)	(26.97)	(26.98)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1245	1245	1245	1245

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village-specific time to market. They also include: total cultivated area. labor force, distance to the market, number of plows, cattle and poultry. Other controls (sex, age, education, province and village dummies) are used to elicit risk and time preferences from the interval regression.

Table 10: Fertilizer Use and Risk and Time Preferences (midpoint of interval)

	[1] Fertilizer (kg)	[2] Fertilizer (kg)	[3] Fertilizer (kg)	[4] Fertilizer (kg)
Risk aversion	4.25	5.86	4.72	6.21
	(5.29)	(5.29)	(5.22)	(5.38)
Discount rate	-47.56**	-48.11**	-155.58**	-157.24**
	(20.05)	(19.68)	(76.42)	(76.53)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1502	1502	1502	1502

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village dummies, total cultivated area, sex, age, education, labor force, province, number of plows, cattle and poultry.

Table 11: Fertilizer Use and Risk and Time Preferences (elicited parameter)

	[1]	[2]	[3]	[4]
	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)
Risk aversion	68.03**	53.12**	76.86**	54.93
	(28.75)	(26.61)	(38.7)	(36.64)
Discount rate	-230.38***	-238.66***	-510.09***	-490.38***
	(75.54)	(75.46)	(172.68)	(191.05)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1497	1497	1497	1497

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village specific time to market. They also include: total cultivated area. labor force, distance to the market, number of plows, cattle and poultry. Other controls (sex, age, education, province and village dummies) are used to elicit risk and time preferences from the interval regression.

Table 12: Maize Area and Risk and Time Preferences (midpoint of interval)

	[1] Maize area (ha)	[2] Maize area (ha)	[3] Maize area (ha)	[4] Maize area (ha)
Risk aversion	0.04	0.02	0.05	0.02
	(0.03)	(0.03)	(0.03)	(0.03)
Discount rate	-0.34*	-0.33**	-1.11**	-1.06**
	(0.15)	(0.15)	(0.52)	(0.52)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1502	1502	1502	1502

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village dummies, total cultivated area, sex, age, education, labor force, province, number of plows, cattle and poultry.

Table 13: Maize Area and Risk and Time Preferences (elicited parameter)

	[1] Maize area (ha)	[2] Maize area (ha)	[3] Maize area (ha)	[4] Maize area (ha)
Risk aversion	0.77***	0.64**	0.83**	0.63*
	(0.27)	(0.25)	(0.35)	(0.35)
Discount rate	-2.15***	-2.28***	-4.27***	-4.16**
	(0.73)	(0.73)	(1.51)	(1.66)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1497	1497	1497	1497

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village specific time to market. They also include: total cultivated area. labor force, distance to the market, number of plows, cattle and poultry. Other controls (sex, age, education, province and village dummies) are used to elicit risk and time preferences from the interval regression.

Table 14: Estimated Time Preference Parameter (hyperbolic preferences à la Prelec)

Parameter	Obs.	Estimation	Mean	Std. Dev.
Discount rate (β, 1 month)	1502	Midpoint	0.25	0.22
Discount rate (β, 1 month)	1349	Elicited	0.22	0.20
Discount rate (β, 4 days)	1502	Midpoint	0.09	0.08
Discount rate (β, 4 days)	1349	Elicited	0.10	0.07
Decreasing impatience ($-\alpha$)	1502	Midpoint	-0.57	0.40
Decreasing impatience ($-\alpha$)	1349	Elicited	-0.47	0.37

Note: This table provides summary statistics for the estimated time preferences.

Table 15: Fertilizer Use and Hyperbolic Preferences (midpoint of interval)

	[1]	[2]	[3]	[4]
	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)
Risk aversion	5.12	6.55	4.75	6.25
	(5.18)	(5.33)	(5.22)	(5.38)
Discount rate	-71.24**	-71.93***	-182.32**	-184.92**
	(27.94)	(27.54)	(92.65)	(91.39)
$-\alpha$ (decreasing discount)	-20.89	-20.9	2.54	2.82
	(20.02)	(20.17)	(22.33)	(22.24)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1502	1502	1502	1502

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village dummies, total cultivated area, sex, age, education, labor force, province, number of plows, cattle and poultry.

Table 16: Fertilizer Use and Hyperbolic Preferences (elicited parameter)

	[1]	[2]	[3]	[4]
	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)	Fertilizer (kg)
Risk aversion	76.96**	59.79*	81.78**	60.72*
	(36.66)	(33.23)	(39.39)	(35.91)
Discount rate	-292.84***	-321.09***	-878.8***	-935.37***
	(104.17)	(100.52)	(288.07)	(280.36)
$-\alpha$ (decreasing discount)	3.8	5.52	40.98	44.66
	(33.98)	(20.17)	(39.79)	(40.34)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1344	1344	1344	1344

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village-specific time to market. They also include: total cultivated area. labor force, distance to the market, number of plows, cattle and poultry. Other controls (sex, age, education, province and village dummies) are used to elicit risk and time preferences from the interval regression.

Table 17: Maize Area and Hyperbolic Preferences (midpoint of interval)

	[1]	[2]	[3]	[4]
	Maize area	Maize area	Maize area	Maize area
Risk aversion	0.05	0.02	0.05	0.02
	(0.03)	(0.03)	(0.03)	(0.03)
Discount rate	-0.52**	-0.49**	-1.41**	-1.35**
	(0.21)	(0.21)	(0.67)	(0.68)
$-\alpha$ (decreasing discount)	-0.12	-0.11	0.05	0.05
	(0.12)	(0.12)	(0.14)	(0.14)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1502	1502	1502	1502

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village dummies, total cultivated area, sex, age, education, labor force, province, number of plows, cattle and poultry.

Table 18: Maize Area and Hyperbolic Preferences (elicited parameter)

	(1)	(2)	(3)	(4)
	Maize Area	Maize Area	Maize Area	Maize Area
Risk aversion	0.82**	0.69**	0.86**	0.68*
	(0.35)	(0.32)	(0.38)	(0.35)
Discount rate	-2.65**	-2.98***	-7.27**	-7.96***
	(1.01)	(0.96)	(2.72)	(2.73)
$-\alpha$ (decreasing discount)	0.39	0.41	0.69*	0.73*
	(0.29)	(0.29)	(0.37)	(0.37)
Delay	1 month	1 month	4 days	4 days
Payoffs	low	high	low	high
Obs.	1344	1344	1344	1344

Note: Standard errors clustered at village level are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include village-specific time to market. They also include: total cultivated area. labor force, distance to the market, number of plows, cattle and poultry. Other controls (sex, age, education, province and village dummies) are used to elicit risk and time preferences from the interval regression.

Figure 1: Location of farmers surveyed