Aspirations, Risk Preferences, and Investments in Agricultural Technologies*

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Abstract

We investigate the relationship between aspirations, risk preferences, and investment in agricultural technologies using data collected among cacao farmers in Ecuador. We first find that an inverted U-shaped relationship between the income aspirations gap and investments exists when considering relatively long-term investments (e.g., farm renovations) but not when considering relatively short-term investments (e.g., fertilizer use). Next, using lab-in-the-field experiments designed to elicit risk preferences, we show that the observed inverted U-shaped relationship is robust to the inclusion of risk preference parameters in our regression specification—a potentially important omitted variable in previous studies. These results demonstrate that aspirations that are ahead, but not too far ahead, of current levels provide the best incentive for relatively long-term investments and suggest the presence of psychological constraints to investment in agricultural technology.

Keywords: Aspirations, Risk, Investment, Agriculture.

JEL Codes: C93, D81, D91, O12, Q12, and Q16.

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1 Introduction

Agricultural and economic development, via the structural transformation, rely on investment in agricultural technologies (Goldstein and Udry, 2008). Such investments are associated with considerable risk and, especially in low- and middle-income countries, missing or limited insurance markets make risk a critical constraint on investment in agricultural technologies (Liu, 2013; Magruder, 2018). A growing literature also finds that aspirations may partially explain investment decisions (Fruttero, Muller and Calvo-Gonzalez, 2021). Specifically, existing empirical results demonstrate that aspirations can be either "too low" or "too high" to inspire risky yet productive investments (Janzen et al., 2017; Ross, 2019; Bloem, 2021; McKenzie, Mohpal and Yang, 2022) and imply the existence of an inverted U-shaped relationship between the aspirations gap (e.g., the distance between and individual's current and aspired levels) and investment choices (Genicot and Ray, 2017). Such a relationship suggests the presence of psychological constraints to investment in agricultural technologies and carries implications for the design of policies and programs that aim to inspire agricultural technology adoption.

In this paper, we study the relationship between aspirations and investment in agricultural technologies while accounting for the influence of risk preferences. To do so, we use data collected among cacao farmers in Ecuador and implement lab-in-the-field experiments to elicit risk preference parameters. We test the theoretical predictions implied in the work of Genicot and Ray (2017), which demonstrate the possibility of an inverted U-shape relationship between the income aspirations gap and investments. Cacao production in Ecuador presents a natural setting to study aspirations, risk preferences, and agricultural investment choices. About 90 percent of Ecuador's cocoa bean production is produced by small farmers cultivating one to five hectares (USDA FAS, 2015), and many of these small-scale cacao farms experience relatively low levels of productivity (Villacis et al., 2022*a*). This low productivity is associated with the use of old plantation tress (i.e., with ages of 60 or more years), the use of less productive varieties, and the scant use of agricultural inputs.[1] Both investments in the use of agricultural inputs and farm renovations can generate positive expected future payoffs. However, investing in these agricultural technologies is risky. In addition, farm renovation using high-yielding cacao tree varieties requires much more time for payoffs to materialize than the seasonal use of agricultural

[1]Agronomic studies find that yields from CCN-51 cacao trees can be four times larger than yields from Nacional cacao trees (Abbott et al., 2018). Some of this yield differential is likely also attributable to less intensive use of agricultural inputs—such as fertilizer—on farms with Nacional trees compared to farms with CCN-51 trees (Amores et al., 2011).

inputs—such as fertilizer. Therefore, an investigation into how income aspirations and risk preferences influence investment in agricultural technologies fits well in the context of cacao cultivation in Ecuador.

We find two key results. First, we find an inverted U-shaped relationship exists when considering expenditures in farm renovations—an investment with a relatively long-term payoff schedule. We do not, however, find evidence of an inverted U-shaped relationship when considering expenditures on fertilizer—an investment with a relatively short-term payoff schedule. This is an important finding because although several studies test for an inverted U-shaped relationship or behavior consistent with "aspirations frustration" (Janzen et al., 2017; Ross, 2019; Bloem, 2021; McKenzie, Mohpal and Yang, 2022), none of these studies examine investments in *agricultural* technologies. Second, we show that the observed inverted U-shaped relationship is robust to the inclusion of experimentally-elicited risk preference parameters in our regression specifications. This is an important finding because although risk preferences are an important factor for understanding agricultural investment behavior (Liu, 2013), the existing literature investigating the inverted U-shaped relationship with observational data has yet to directly account for variation associated with risk preferences in formal regression analysis. Therefore, risk preferences are a potentially important omitted variable in these previous studies.[2]

Our paper contributes to the literature investigating how aspirations inspire future-oriented behavior (Lybbert and Wydick, 2017; Bernard et al., 2018; McKenzie, Mohpal and Yang, 2022). In particular, our analysis is most closely related to a sub-set of these studies that test for an inverted U-shaped relationship between the aspirations gap and future-oriented behavior—such as investment and saving (Janzen et al., 2017; Ross, 2019; Bloem, 2021). Moreover, our analysis also intersects with the recent work of Knapp, Wuepper and Finger (2021) who integrate measures of risk preferences, personality traits, and aspirations in regressions predicting farmers' farm management choices. They find that psychological personality traits, aspirations, and risk preferences each predict specific types of choices among fruit growers in Switzerland.

Our work, however, differs from these previous studies and contributes to an understanding of the role of aspirations in the process of agricultural development in two particular ways. First, we specifically contribute to the literature investigating the existence of an

[2]In particular, Bloem (2021) notes the following: "The relationship between the aspirations gap and investment choices may be endogenous due to multiple sources of unobserved heterogeneity. [...] For example, if those who hold more extreme risk preferences (e.g., extreme risk loving or extreme risk averse) invest relatively little in the future and if these preferences are correlated with aspirations, then it may be the case that the observed correlations [...] are spurious."

inverted U-shaped relationship between the aspirations gap and future-oriented behavior with observational data (Janzen et al., 2017; Ross, 2019; Bloem, 2021) in three important areas. Most fundamentally, we study investments in agricultural technologies, which have yet to be formally linked with the aspirations gap in any existing empirical study. Next, we differentiate between investments with long-term vs. short-term payoffs, which is a yet-to-be explored source of heterogeneity. Finally, with experimentally elicited measures of risk preferences, we are able to account for a potentially important omitted variable in the previous studies using observational data.

Second, we contribute to the classic literature on the adoption of high-yielding agricultural technologies in low- and middle-income countries (Foster and Rosenzweig, 2010; Magruder, 2018). We specifically link the study of the role of aspirations in inspiring investment behavior to the seemingly puzzling observation of farmers refraining from investing in welfare-improving agricultural technologies (Mobarak and Saldanha, 2022). Although a number of explanations that draw from the psychology or behavioral literature help explain the farmer's technology adoption decision—such as self-control or commitment problems (Duflo, Kremer and Robinson, 2011)—other than the recent insights of Knapp, Wuepper and Finger (2021), our understanding of how aspirations relate to investment in agricultural technologies remains limited.

The remainder of this paper is organized as follows. In the next section, we briefly introduce the study setting, motivate the study of aspirations and investments, and discuss how we measure key variables. In section 3 we discuss our empirical strategy for estimating the relationship between the aspirations gap and investments in agricultural technologies. In section 4 we present our main results and discuss a variety of robustness checks. Finally, section 5 concludes.

2 Study Setting and Data

Fieldwork for the data collection effort of this study was conducted between August and December 2021 in five coastal provinces of Ecuador (i.e., Esmeraldas, Guayas, Los Ríos, Manabí, and Santo Domingo de los Tsáchilas—see Figure A1 in the Supplemental Appendix) in partnership with the Ecuadorian Institute of Agricultural Research (INIAP). These provinces represent 80 percent of the total cacao area planted in the country (CFN, 2018). In a random subset of 25 villages, we conducted a household survey and lab-in-the-field experiments designed to elicit individual risk preferences. In total, our data include 523 cacao farmers from the 25 randomly selected villages in the five coastal provinces of

Ecuador mentioned above. Over the course of the past decade, most of these villages were part of a nationwide INIAP extension program that promoted the adoption of pruning practices to rehabilitate older and non-productive cacao plantations. The household survey and the experimental sessions lasted about two hours for each farmer. Before the meetings, INIAP contacted village leaders by phone and asked them for cooperation and help in recruiting subjects. Village leaders were instructed to inform community members about the data collection visit logistics as well as any benefits or risks associated with participation in the study.

2.1 Aspirations and Investments

Seminal work by Genicot and Ray (2017) developed a model whereby aspirations that are ahead, but not too far ahead, of current levels provide the best incentive for investment choices. This theoretical model provides an empirically testable prediction of an inverted U-shaped relationship between the income aspirations gap and investments with possible positive returns in future income.

In the model developed by Genicot and Ray (2017), which is further summarized by Janzen et al. (2017) and Bloem (2021), aspirations are modeled as an inter-temporal utility function with a reference point (Kahneman and Tversky, 1979). Importantly, aspiration achievement leads the individual to realize some level of "bonus" utility. This "bonus" utility leads to a piece-wise benefits function. In this benefits function, the net benefit in terms of utility is defined as the discounted net present value of consumption for income levels below some level of aspiration. For income levels above some level of aspiration, the individual realizes this discounted net present value plus the "bonus" utility.

If the aspiration is achieved or "satisfied" then there is a positive relationship between the aspiration gap and investment. However, if the aspiration is not achieved or "frustrated" then there is a sudden decrease in the level of investment. The point at which aspirations switch from being "satisfied" to being "frustrated" represents and individual's turning point in their own individual relationship between their aspirations gap and their investment choices. If every individual held the same turning point value in their income aspiration gap relative to some investment choice, then we would see an upward-sloping relationship between the aspirations gap and investment with a discontinuous drop at this unanimous turning point value. Given the heterogeneity in the location of each individual's turning point, however, an inverted U-shaped relationship will form between the income aspirations gap and investment choices within a population of individuals. We

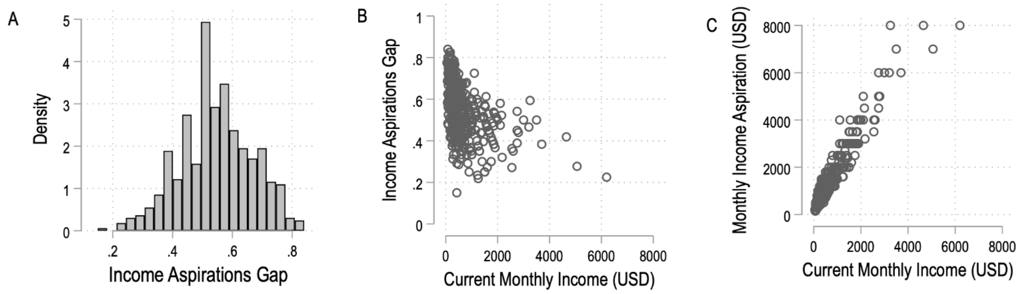

FIGURE 1: Income Aspirations and the Income Aspirations gap

Note: This figure illustrates the distribution of the income aspirations gap and its relationship with monthly income.

test for this relationship, and aim to distinguish between long-term and short-term investments, using data from cacao farmers in Ecuador.

We measure the aspirations gap by first asking participants to assess their current monthly income from farming activities. Next, we follow Bernard and Taffesse (2014) and ask participants the level of monthly income they would like to achieve in their life. Following Janzen et al. (2017) and Bloem (2021), we define the aspirations gap as the difference between these two answers divided by the income aspiration, as follows:

$$\text{Income aspirations gap} = \frac{\text{income aspiration} - \text{current income}}{\text{income aspiration}} \tag{1}$$

Panel A in Figure 1 shows a histogram with the distribution of the income aspirations gap. Values of the income aspirations gap are bounded between zero and one. In our data, none of our respondents report an aspirations gap at the extreme values of zero (i.e., representing current income equalling income aspiration) or one (i.e., representing zero current income). Panel B of Figure 1 illustrates the relationship between current income and the income aspirations gap and shows that the income aspirations gap tends to be higher for households at the lower end of the income distribution. Finally, panel C of Figure 1 shows that, on average, income aspirations are higher than households' level of income.

2.2 Risk Preferences

We measure risk preferences in two ways: First, using lab-in-the-field experiments we elicit prospect theory risk preference parameters (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) using incentivized lottery games. Second, we also ask participants a series of statements taken from the Domain-Specific Risk-Taking (DOSPRT) scale (Blais and Weber, 2006; Weber, Blais and Betz, 2002).

Previous studies use prospect theory and test its role in a variety of different agricultural settings (Tanaka, Camerer and Nguyen, 2010; Liu, 2013; Bocquého, Jacquet and Reynaud, 2014; Villacis, Alwang and Barrera, 2021). We use prospect theory as a key conceptual basis linking farmer's risk preferences to investment decisions for two main reasons. First, and in contrast to expected utility theory, prospect theory provides a more comprehensive conceptualization of risk preferences as it helps account for loss aversion and the presence of status quo bias (Starmer, 2000). This is important because status quo bias in technology adoption could potentially explain why farmers do not renovate plantations and adopt high-yielding varieties (Liu, 2013; Mullainathan, 2007). Second, in the theoretical model of aspirations and investment choices, Genicot and Ray (2017) model aspirations as reference points in a utility function that draws heavily on insights from prospect theory (Kahneman and Tversky, 1979).

To elicit and measure prospect theory risk parameters, we use a lottery game based on the experimental design of Tanaka, Camerer and Nguyen (2010) and customized for agricultural settings by Villacis, Alwang and Barrera (2021). This adaptation of the experimental design seeks to ease the understanding of highly complex lottery games for participants and has previously been implemented in Ecuador. Probabilities and payoffs are shown to participants by illustrating a farm composed of 10 equally sized lots. The lot's particular payoffs from using two types of technologies, either Seed A or Seed B, accompany the illustration (See Figure A2 in the Supplemental Appendix).

As in Villacis, Alwang and Barrera (2021), participants were told that at the end of each year only one random lot out of the ten would survive. Thus, they need to decide at which year they would "switch" from Seed A to Seed B. Participants received $5 USD for showing up to the experimental sessions and received a bonus that ranged from -$4 to $4 USD based on their actual choices during play.[3] The average earning for participating in the games was $7.50 USD, roughly the wage of a one-half working day for cacao harvesting activities. Illiterate farmers were not allowed to join the experiment.

Results of the estimation of the prospect theory risk preference parameters are aligned with previous empirical findings (Tanaka, Camerer and Nguyen, 2010; Liebenehm and Waibel, 2014; Villacis, Alwang and Barrera, 2021). The average of the risk aversion parameter (σ) is 0.62, indicating that the average participant is relatively risk-averse. The average

[3]See Villacis, Alwang and Barrera (2021) for more details on the experimental procedures and the incentivized payments.

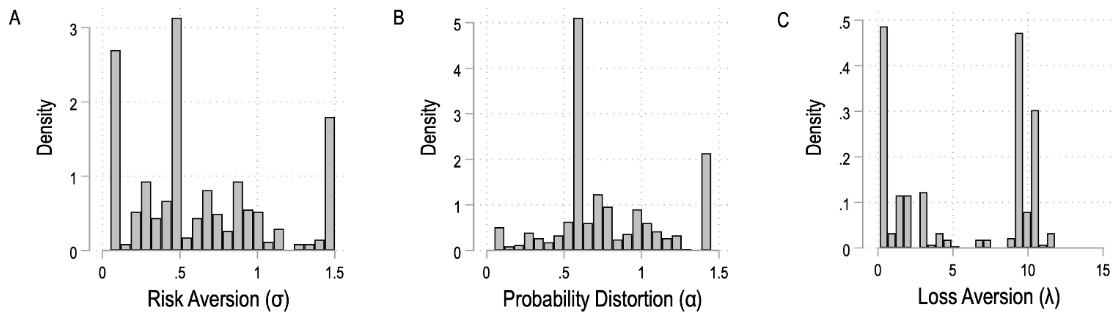

FIGURE 2: Distribution of Prospect Theory Risk Preference Parameters

Note: This figure illustrates the distribution of the risk preference parameters elicited using prospect theory.

of the probability distortion parameter (α) is 0.78, suggesting that on average, people tend to overweight low probabilities. The average of the loss aversion parameter (λ) is 5.55, indicating that people are more sensitive to losses than to gains, at a magnitude of roughly five to one. Figure 2 shows the distributions of the parameters σ, α, and λ. The mean values of α and λ are significantly different from one, providing us further evidence to reject an expected utility framework in favor of the prospect theory framework.

As an alternative measure of risk preferences, we use the DOSPERT investing sub-scale to evaluate participants' risk-taking behavior. Given risk-taking is often domain specific, the DOSPERT scale assesses risk-taking in six domains: gambling, investing, ethical choices, and behaviors relating to health/safety, social interaction, and recreation (Blais and Weber, 2006; Weber, Blais and Betz, 2002). The DOSPERT questions from the investing sub-scale prompted participants to rate the risk associated with activities such as investing 10 percent of their annual income in a new business venture. The scale in each question ranges from one (not at all risky) to seven (extremely risky).[4] We sum the items in the DOSPERT investing sub-scale to obtain a single score. As shown in Table 1, out of 21 possible points, the mean DOSPERT investing sub-scale value across individual farmers is 11.44 with a standard deviation of 3.74. Table A1 in the Supplemental Appendix reports the raw correlation between each of our risk preference parameters. These results show that there is a low correlation between the DOSPERT investing sub-scale index and each of the prospect theory risk preference parameters.

Summary statistics for each of the main variables that we use in this paper are shown in Table 1. Fertilizer expenditures are measured as the average expenses on fertilizer (includ-

[4]The DOSPERT identification of different degrees of risk taking in its six domains has been replicated in a wide range of populations and real-world settings (Figner and Weber, 2011).

TABLE 1: Summary Statistics

	(1) Mean	(2) Std. Dev.	(3) Min.	(4) Max.	(5) Obs.
Panel A: Key Variables					
Income aspiration gap	0.543	0.122	0.15	0.84	523
Farm renovation expenditures (USD)	194.67	563.20	0	5,000	523
Fertilizer expenditures (USD)	256.03	835.29	0	16,200	523
Dospert investing index	11.44	3.74	3	21	523
PT Risk aversion (σ)	0.621	0.452	0.05	1.5	523
PT Probability distortion (α)	0.779	0,354	0.05	1.45	523
PT Loss aversion (λ)	5.55	4.33	0.12	11.79	523
Panel B: Sample Characteristics					
Age	49.47	15.63	17	87	523
Gender (female = 1)	0.268	0.443	0	1	523
Household size	4.08	1.72	1	10	523
Year of education	10.37	4.13	0	17	523
Area of cacao cultivation (hectares)	2.56	2.58	0.1	30	523
Cacao farming experience (years)	19.86	15.53	1	70	523
Annual income (USD)	8,915.68	9,133.60	800	72,000	523
Plantation age (years)	18.25	16.84	1	80	523

Notes: These summary statistics describe each of the key variables in our analysis along with other relevant variables that describe the composition of our sample of cacao farmers.

ing labor and inputs) during the last five years. Likewise, farm renovations expenditures are measured as the average expenses on farm renovation (including labor and inputs) during the last five years.[5]

3 Estimation Strategy

Credibly estimating the relationship between the aspirations gap and investment choices presents an empirical challenge. In particular, socially determined aspirations along with investment choices may both be influenced by a host of both observable and unobservable factors. Thus, designing and implementing an experimental study that exogenously influences an individual's aspirations may seem like a natural avenue for research. As discussed by McKenzie, Mohpal and Yang (2022), however, ethical issues complicate the feasibility of such an empirical approach. Given the existing theoretical (Genicot and Ray, 2017) and empirical evidence—using both experimental (McKenzie, Mohpal and Yang, 2022) and observational data (Janzen et al., 2017; Ross, 2019; Bloem, 2021)—documenting that raising aspirations could have a negative effect on psychological and economic well-being, the ethical feasibility of an experimental study that exogenously increases aspira-

[5]We use a time horizon of five years due to cacao trees normally requiring five years after planted to bear fruits and be harvested (Amores et al., 2011)

tions is questionable. Therefore, the best way forward to understand the relationship between the aspirations gap and investment choices may be carefully using and interpreting econometric methods with observational data.

Our estimation approach builds on that used in previous studies testing for an inverted U-shape relationship between the income aspirations gap and investment choices with observational data (Janzen et al., 2017; Bloem, 2021). We specifically estimate two regression specifications. One that imposes a quadratic functional form on the aspirations gap variable and another that allows the aspirations gap variable to enter into the regression specification non-parametrically. The first method estimates the following equation:

$$y_{ie} = \beta_0 + \beta_1 g_{ie} + \beta_2 g_{ie}^2 + \beta_3 r_{ie} + \mathbf{X'_{ie}}\mathbf{\Gamma} + \theta_e + \epsilon_{ie} \quad (2)$$

In this equation, y_{ie} is the outcome variable of interest for farmer i in canton (e.g., geographic location) e and represents a farmer's expenditure on either farm renovations or fertilizer. The g_{ie} variable represents the income aspirations gap and g_{ie}^2 represents the squared income aspirations gap. The variable, r_{ie}, controls for the farmer's risk preferences using either the Dospert investing index or prospect theory risk parameters (e.g., risk aversion, probability distortion, and loss aversion). The vector $\mathbf{X_{ie}}$ represents a set of control variables. These control variables include respondent age, age squared, household size, whether or not the respondent has a child, respondent gender, whether or not the farmer is a member of a farmer's association, education level, total area of cacao cultivation, area of cacao cultivation squared, years of experience as a cacao farmer, age of the farm, and current level of income. Finally, θ_e are canton fixed effects and ϵ_{ie} is the error term. The standard errors are clustered at the canton level. An inverted U-shape relationship exists if, given an interval of values of $g \in [g_l, g_h]$, $\beta_1 + 2\beta_2 g_l > 0$ and $\beta_1 + 2\beta_2 g_h < 0$ (Lind and Mehlum, 2010).

The second method estimates a semi-parametric regression specification as follows:

$$y_{ie} = \delta_0 + f(g_{ie}) + \delta_1 r_{ie} + \mathbf{X'_{ie}}\mathbf{\Xi} + \rho_e + \nu_{ie} \quad (3)$$

This estimation equation is nearly identical to equation 2 except that the g_{ie} variable enters into the equation non-parametrically. This allows for a more flexible relationship between g_{ie} and y_{ie}, rather than one that imposes a specific quadratic functional form as in equation 2. Again r_{ie} represents the farmer's risk preferences, $\mathbf{X_{ie}}$ is the same vector of control variables, ρ_e are canton fixed effects, ν_{ie} is the error term, and the standard errors are clustered at the canton level. Following Bloem (2021), we estimate this semi-parametric regression using the double residual semi-parametric approach developed by Robinson (1988). This estimator first partials out the non-parametric part of the regression by removing conditional expectations of the parametric part of the regression. In the next step, a local polynomial smoothing function characterizes the residualized non-parametric relationship between g_{ie} and y_{ie}.

Although we account for important and previously omitted variation associated with individual-level risk preferences, the estimates generated by equations 2 and 3 may still be biased from unobserved heterogeneity. We account for this possibility of remaining bias in two ways. First, following Bloem (2021), we implement the unobservable selection and coefficient stability approach of Oster (2019) to test the sensitivity of our results to possible bias driven by unobserved heterogeneity. Second, following Janzen et al. (2017), we note that it is difficult to imagine a specific form of unobserved heterogeneity—especially after accounting for risk preferences—that would lead to an inverted U-shaped relationship between the aspirations gap and investment choices.

4 Results

In this section, we present results from our two estimation approaches. First, in Tables 2 and 3, we present results from estimating equation 2 imposing a quadratic functional form on the aspirations gap variable. Second, in Figure 3, we present the non-parametric fit of the relationship between the income aspirations gap and investment in agricultural technologies from estimating equation 3 using a semi-parametric approach. Finally, in Table 4 we present results using a sub-sample of our data to demonstrate the robustness of our core results. Additional robustness tests, which we discuss in more detail in section 4.3, are presented in the Supplemental Appendix.

4.1 Farm Renovation Expenditures

We begin by studying farmer's expenditure on farm renovations, which represents an investment with a relatively long-term payoff schedule. As cacao trees productivity declines due to ageing and other causes, renovating a cocoa orchard represents a means to enhance future production and farm revenue. In addition to the associated expenses, cacao farm renovations have a relatively long waiting period (normally four to five years) before starting to reap benefits from the harvest of pods and beans. During the previous decade the

Ecuadorian government led renovation initiatives of low-yielding cocoa plantations heavily affected by pests and diseases—mostly through the provision of free certified seedlings (Villacis et al., 2022*b*).[6]

In Table 2, we report results from estimating equation 2 with the farmer's expenditures in farm renovations as the dependent variable. Column (1) serves as a baseline regression that estimates the relationship between the income aspirations gap and expenditures in farm renovations with no risk preference variables, canton fixed effects, or additional control variables included. In this column, we find strong evidence for an inverted U-shaped relationship. The coefficient on the aspiration gap variable is positive and statistically significant, while the coefficient on the squared aspiration gap variable is negative and statistically significant. Additionally, U-test results reinforce this finding.[7] In particular, we can reject the null hypothesis of a monotonic relationship. The estimated turning point in the inverted U-shaped relationship is at roughly the midpoint in the range of possible values of the income aspirations gap variable.

In column (2) of Table 2 we simply regress the Dospert investing index on the farmer's expenditures in farm renovations to test if these two variables are closely associated together. Indeed, the higher a farmer's score is on the Dospert investing risk index, the more the farmer spends on farm renovations. This result highlights that the Dospert investing variable is a relevant variable when considering expenditures on farm renovations. Next, in column (4), we include the Dospert investing index into our main regression specification estimating the relationship between the income aspirations gap and expenditures in farm renovations. Similar to the results in column (1), and despite the fact that column (4) accounts for the farmer's risk preferences with the Dospert investing index, we again find strong evidence for an inverted U-shaped relationship. The coefficient on the aspiration gap variable remains positive and statistically significant while the coefficient on the squared aspiration gap variable remains negative and statistically significant. Additionally, U-test results reinforce this finding.

We implement several robustness and sensitivity checks on these results. First, we estimate equation (1) with canton fixed effects to account for any unobservable geographic heterogeneity at the canton level and with the full vector of additional control variables. We show these results in column (5) of Table 2 and again find strong evidence for an in-

[6]It is estimated that almost 10 million seedlings were donated to cover approximately 14,000 hectares of new cacao plantations (MAGAP, 2017).

[7]The U-test tests for a non-monotonic relationship by testing the null hypothesis of a monotonic relationship if both H_0^L and H_0^H are rejected at a given level of statistical significance. Here H_0^L tests if $\alpha_1 + 2\alpha_2 g_l \leq 0$ vs. $\alpha_1 + 2\alpha_2 g_l > 0$ and H_0^H tests if $\alpha_1 + 2\alpha_2 g_h \geq 0$ vs. $\alpha_1 + 2\alpha_2 g_h < 0$ (Lind and Mehlum, 2010).

TABLE 2: Farm Renovation Expenditures, Long-Term Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aspiration gap	2,608***			2,759***	2,598**	2,558***	2,327**
	(630.1)			(638.4)	(1,049)	(634.1)	(1,056)
Squared aspiration gap	-2,620***			-2,762***	-2,542**	-2,547***	-2,250**
	(580.5)			(597.9)	(878.6)	(576.1)	(860.2)
Dospert investing index		13.29**		14.11**	14.33		
		(4.644)		(5.069)	(8.716)		
PT risk aversion (σ)			-25.11			-23.29	-50.78
			(43.73)			(45.68)	(55.03)
PT probability distortion (α)			84.67			74.19	63.55
			(53.58)			(54.53)	(58.80)
PT loss aversion (λ)			-5.716			-5.014	-4.711
			(6.875)			(7.165)	(7.082)
Observations	523	523	523	523	523	523	523
R-squared	0.010	0.008	0.004	0.019	0.070	0.014	0.065
Canton fixed effects?	No	No	No	No	Yes	No	Yes
Additional controls?	No	No	No	No	Yes	No	Yes
U-test results:							
Turning point	0.497			0.499	0.511	0.502	0.515
Fieller 95% CI	[0.438; 0.536]			[0.446; 0.538]	[0.438; 0.551]	[0.435; 0.545]	[0.412; 0.565]
Sasabuchi p-value	0.000			0.000	0.003	0.001	0.005
Slope at min	1,822.5			1,930.5	1,830.8	1,793.8	1,631.9
Slope at max	-1,792.7			-1,881.6	-1,671.3	-1,721.6	-1,452.3

Notes: This table reports ordinary least squares (OLS) regression estimates with total farm renovation expenditures as the dependent variable. The aspirations gap represents the difference between an individual's aspired monthly income and their current monthly income divided by their aspired monthly income. The Dospert investing variable represents a psychometric scale that assesses risk-taking in investment behavior. The risk aversion, probability distortion, and loss aversion variables are prospect theory risk preference parameters. Standard errors clustered at the canton level are reported in the parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

verted U-shaped relationship between the income aspirations gap and expenditures in farm renovations. Again, U-test results are able to formally reject the null hypothesis of a monotonic relationship.

In a second robustness check, we use prospect theory risk preference parameters measuring risk aversion, probability distortion, and loss aversion as an additional measure of risk preferences. Column (3) in Table 2 simply estimates how these measures of risk preferences correlate with expenditures on farm renovation and shows that none of these measures are statistically significant at conventional levels. Nevertheless, when we include these variables into our main regression specification estimating the relationship between the income aspirations gap and expenditures in farm renovations, in column (6) of Table 2, we continue to find strong evidence of an inverted U-shaped relationship. Finally, in column (7) of Table 2, we included canton fixed effects and additional control variables and find that the observed inverted U-shape relationship is robust to the inclusion of these variables as well.

As a final sensitivity check, we implement the coefficient stability and unobservable selection approach formalized by Oster (2019). This approach allows for the estimation of a proportional selection coefficient (noted as "Oster's delta") based on a comparison of the coefficients of interest and the R-squared in a "short" regression and in a "long" regression.[8] We first compare the results in column (1) with the results in column (4), which includes the Dospert investing variable. The R-squared almost doubles in size between columns (1) and (4), but the coefficients on the aspirations gap and squared aspirations gap measures remain stable. In fact, the coefficients are larger in absolute value in column (4) than in column (1), which Oster (2019) notes implies robustness to unobservable selection bias. Next, we compare the results in column (1) with the results in column (5), which includes not only the Dospert investing variable, but also the full set of controls and canton fixed effects. Oster's delta for the aspirations gap and the squared aspirations gap variables in column (5) are 16.70 and 14.83, respectively, providing strong support for robustness to potential unobservable selection bias. As Oster (2019) notes, any omitted variables would need to be 17 and 15 times, respectively, more important than the included variables to explain away these results.

Next, we compare the results in column (1) with the results in column (6), which include the prospect theory risk variables. The R-squared increases by nearly 50 percent, but again the coefficients on the aspirations gap and squared aspirations gap measures

[8]Oster's delta, or the proportional selection coefficient, can be estimated using the `psacalc` command in Stata.

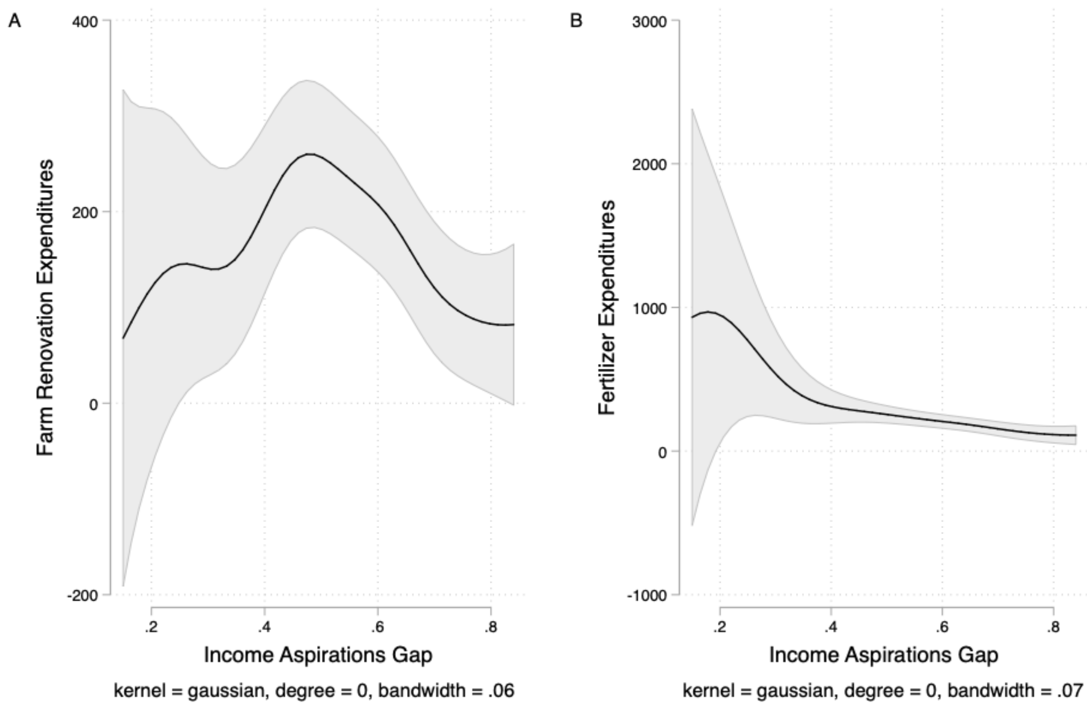

FIGURE 3: Non-parametric Regression

Note: This figure illustrates non-parametric estimates of the relationship between the aspirations gap and agricultural investments while controlling for the Dospert investing measure of risk preference. Panel A uses farm renovation expenditures as a measure of investment. Panel B uses fertilizer expenditures as a measure of investment.

remain stable.These results provide support for robustness to potential unobservable selection bias. Finally, we compare the results in column (1) with the results in column (7), which includes not only the prospect theory variables, but also the full set of controls and canton fixed effects. Oster's delta for the aspirations gap and the squared aspirations gap variables in column (7) are 8.79 and 7.81, respectively. These results provide further evidence of the robustness of our results to potential unobservable selection bias.

We now turn to our second estimation approach using the semi-parametric regression specification in equation 3. Panel A of Figure 3 plots the non-parametric fit of the relationship between the income aspirations gap and expenditures in farm renovation, controlling for the Dospert investing measure of risk preferences. These results visually support the parametric results reported in Table 2. As the income aspiration gap increases, so does expenditures on farm renovations, but only up to about the midpoint in the range of possible values in the income aspirations gap measure. After roughly the midpoint, as the income aspirations gap increases expenditures on farm renovations decline.

4.2 Fertilizer Expenditures

We now turn to studying farmer's fertilizer expenditure. Fertilization is generally viewed as a beneficial management practice and represents an investment with a relatively short-term payoff schedule. However, in our sample, only 53 percent of farmers report using fertilizer, and other studies have reported even lower use of fertilizer among cacao farmers in Ecuador (Barrera et al., 2019). Older plantations being less intensively managed and differences in agronomic practices related to the use of different varieties often limit production output (USDA FAS, 2015).

In Table 3, we report results from estimating equation 2 with the farmer's fertilizer expenditures as the dependent variable. Column (1) again serves as a baseline regression that estimates the relationship between the income aspirations gap and fertilizer expenditures with no risk preference variable, canton fixed effects, or additional control variables included. In this column, we do not find evidence for an inverted U-shaped relationship. In fact, the coefficient on the aspiration gap variable is negative and not statistically significant at conventional levels. In addition, the coefficient on the squared aspiration gap variable is positive and not statistically significant at conventional levels. Additionally, the U-test results show that we fail to reject a monotonic relationship between the income aspirations gap and fertilizer expenditures.

In column (2) of Table 3, we again simply regress the Dospert investing index on the farmer's fertilizer expenditures to test if these two variables are closely associated with each other. Indeed, similar to the results in Table 2, the higher a the farmer's scores on the Dospert investing index, the more the farmer spends on fertilizer. This result highlights that the Dospert investing index is a relevant variable when considering fertilizer expenditures. Next, in column (4), we include the Dospert investing index in our main regression specification estimating the relationship between the income aspirations gap and fertilizer expenditures. Similar to the results in column (1), we again do not find evidence for an inverted U-shaped relationship.

The remainder of the results in Table 3 continues to support the observation of no inverted U-shaped relationship between the income aspirations gap and fertilizer expenditures. Column (5) of Table 3 includes canton fixed effects and additional control variables, and again, shows no evidence of an inverted U-shape relationship. Column (6) includes prospect theory risk preference parameters in the regression specification. Despite the fact

TABLE 3: Fertilizer Expenditures, Short-Term Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aspiration gap	-5,038			-4,926	-138.4	-5,149	-230.1
	(5,850)			(5,880)	(696.6)	(5,868)	(809.8)
Squared aspiration gap	3,698			3,592	112.9	3,850	209.1
	(4,772)			(4,803)	(499.4)	(4,827)	(594.8)
Dospert investing index		11.29**		10.52**	3.528		
		(4.349)		(4.262)	(6.042)		
PT risk aversion (σ)			-160.8			-167.6	-104.4**
			(139.0)			(142.6)	(44.34)
PT probability distortion (α)			85.03**			67.39*	72.02
			(31.22)			(38.14)	(44.27)
PT loss aversion (λ)			-24.34			-22.40	0.0958
			(19.55)			(17.81)	(3.432)
Observations	523	523	523	523	523	523	523
R-squared	0.031	0.003	0.015	0.033	0.743	0.044	0.747
Canton fixed effects?	No	No	No	No	Yes	No	Yes
Additional controls?	No	No	No	No	Yes	No	Yes
U-test results:							
Turning point	0.681			0.685	0.761	0.669	0.733
Fieller 95% CI	$[-\infty; \infty]$			$[-\infty; \infty]$	$[-\infty; \infty]$	$[-\infty; \infty]$	$[-\infty; \infty]$
Sasabuchi p-value	0.297			0.310	0.373	0.282	0.322
Slope at min	-3,928.7			-1,848.2	-1,097,3	-3,993.5	-1,154
Slope at max	1,174.8			1,108.4	141.17	1,319.8	212.01

Notes: This table reports ordinary least squares (OLS) regression estimates with total fertilizer expenditures as the dependent variable. The aspirations gap represents the difference between an individual's aspired monthly income and their current monthly income divided by their aspired monthly income. The Dospert investing variable represents a psychometric scale that assesses risk-taking in investment behavior. The risk aversion, probability distortion, and loss aversion variables are prospect theory risk preference parameters. Standard errors clustered at the canton level are reported in the parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

that at least one of these variables is a relevant predictor of fertilizer expenditures, again shows no evidence of an inverted U-shape relationship. Finally, column (7) shows a similar finding when canton fixed effects and additional control variables are included in the regression specification.

Finally, we turn to our second estimation approach using the semi-parametric regression specification in equation 3. Panel B of Figure 3 plots the non-parametric fit of the relationship between the income aspirations gap and fertilizer expenditures controlling for the Dospert investing measure of risk preferences. These results visually support the parametric results reported in Table 3 that did not find evidence of an inverted U-shaped relationship. If anything, there seems to be a slight monotonically negative relationship. As the income aspiration gap increases, fertilizer expenditures decline.

4.3 Robustness Tests

We now further investigate the robustness of our main finding that aspirations that are ahead, but not too far ahead, of current levels provide the best incentive for relatively long-term investments. We test robustness in three ways. First, we estimate results on the sub-sample of our data that reports more than zero farm renovation expenditures. Next, we estimate results by considering unobserved heterogeneity at the experimental session level. Finally, following Liu (2013), we use an alternative representation of the PT risk preference parameters elicited in our experimental sessions.

In this sub-section, we show the results of the analysis on the sub-sample with at least some farm renovation expenditures. This analysis is motivated by the distribution of farm renovation expenditures in our sample being both highly skewed and containing many zeros. As this raises concerns about a possible spurious relationship driven by the shape of this distribution, we limit our sample to only those farmers who have more than zero farm renovation expenditures. In doing so, we more precisely estimate the relationship between the income aspirations gap and *intensive margin* investment expenditures.

In Table 4, we report results from estimating equation 2 using the sub-sample of farmers with greater than zero farm renovation expenditures. Similar to the other tables in this paper, Column (1) serves as a baseline regression that estimates the relationship between the income aspirations gap and expenditures in farm renovations with no risk preference variable, canton fixed effects, or additional control variables included. In this column, even among a restricted sub-sample, we find strong evidence for an inverted U-shaped relationship. The coefficient on the aspiration gap variable is positive and statistically significant,

TABLE 4: Robustness Test, Sub-sample with > 0, Farm Renovation Expenditures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aspiration gap	5,949***			6,105***	5,247**	5,568***	3,976*
	(1,972)			(1,895)	(2,029)	(1,565)	(1,996)
Squared aspiration gap	-6,041***			-6,197***	-4,765***	-5,705***	-3,581**
	(1,728)			(1,658)	(1,453)	(1,350)	(1,585)
Dospert investing index		25.53**		26.69**	35.66**		
		(10.24)		(11.29)	(14.83)		
PT risk aversion (σ)			-137.3			-127.3	-279.1
			(156.5)			(150.3)	(195.8)
PT probability distortion (α)			87.12			84.23	20.34
			(97.00)			(95.27)	(117.3)
PT loss aversion (λ)			-16.55			-11.84	-21.20
			(22.00)			(21.92)	(27.42)
Observations	180	180	180	180	180	180	180
R-squared	0.026	0.014	0.007	0.042	0.195	0.031	0.190
Canton fixed effects?	No	No	No	No	Yes	No	Yes
Additional controls?	No	No	No	No	Yes	No	Yes
U-test results:							
Turning point	0.492			0.493	0.551	0.488	0.555
Fieller 95% CI	[0.351; 0.545]			[0.367; 0.547]	[0.248; 0.653]	[0.373; 0.545]	[-0.78; 0.814]
Sasabuchi p-value	0.007			0.005	0.017	0.003	0.041
Slope at min	4,137.0			4,246.5	3,817.6	3,856.8	2,902.2
Slope at max	-4,199.0			-4,304.7	-2,758.0	-4,016.3	-2,038.9

Notes: This table reports ordinary least squares (OLS) regression estimates with total farm renovation expenditures as the dependent variable on the sub-sample of farmers with at least some farm renovation expenditures. The aspirations gap represents the difference between an individual's aspired monthly income and their current monthly income divided by their aspired monthly income. The Dospert investing variable represents a psychometric scale that assesses risk-taking in investment behavior. The risk aversion, probability distortion, and loss aversion variables are prospect theory risk preference parameters. Standard errors clustered at the canton level are reported in the parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

while the coefficient on the squared aspiration gap variable is negative and statistically significant. In column (2) of Table 4, we again simply regress the Dospert investing index on the farmer's expenditures in farm renovations to test if these two variables are closely associated together. Again we find that the higher a the farmer's scores on the Dospert investing index, the more the farmer spends on farm renovations. Next, in column (4), we include the Dospert investing index into our main regression specification estimating the relationship between the income aspirations gap and expenditures on farm renovations. We again find strong evidence for an inverted U-shaped relationship.

In the remainder of the results in Table 4, we continue to find evidence for an inverted U-shaped relationship between the income aspirations gap and expenditures in farm renovations. Column (5) of Table 4, includes canton fixed effects and additional control variables, and the inverted U-shaped relationship persists. Column (6) includes prospect theory risk preference parameters in the regression specification and again shows evidence of an inverted U-shape relationship. Finally, column (7) shows similar, albeit slightly weaker, results when canton fixed effects and additional control variables are included in the regression specification. Taken together, the results in Table 4 support the core finding in our paper that there exists an inverted U-shape relationship between the income aspirations gap and farm renovation expenditures, even conditional on various risk preference parameters.

We present the additional robustness tests in the Supplemental Appendix. In particular, Table A2 reproduces the results from Table 2 in the main manuscript but accounts for potential unobserved heterogeneity at the experimental session level. To do this we cluster the standard errors in all specifications at the experimental session level, and include experimental session fixed effects. The results are qualitatively similar to those shown in Table 2. Finally, Table A3 reproduces some of the results from Table 2 in the main manuscript using an alternative representation of the elicited prospect theory risk preference parameters. Particularly, we follow Liu (2013) and replace the values of λ with a dummy variable equal to one to indicate individuals who are loss averse (i.e., $\lambda > 1$). We also replace the values of α with a dummy variable equal to one to indicate individuals who put excessive decision weight on small probabilities (i.e., $\alpha < 1$). Again, the results are qualitatively similar to those shown in Table 2.

5 Conclusion

The structural transformation, whereby the role of the agricultural sector declines relative to the manufacturing sector in an economy, leads to agricultural and economic development (Lewis, 1954; Kuznets, 1957). This structural transformation nearly always requires investment in agricultural technologies. In this paper, we investigate the relationship between aspirations, risk preferences, and investment in agricultural technologies among cacao farmers in Ecuador.

Our analysis leads to two key results. First, we find that an inverted U-shaped relationship between the income aspirations gap and investments exists when considering investments with a relatively long-term payoff schedule (e.g., farm renovations) and does not exist when considering investments with a relatively short-term payoff schedule (e.g., fertilizer use). Thus, the length of the payoff schedule represents an important source of heterogeneity in understanding how aspirations may influence investment choices. Second, we find that the observed inverted U-shaped relationship is robust to the inclusion of experimentally-elicited risk preference parameters in our regression specifications. Risk preferences, particularly in the context of investment in agricultural technologies, are an important factor for understanding investment behavior (Liu, 2013) and thus represent a potentially important omitted variable.

Our results demonstrate that aspirations that are ahead, but not too far ahead, of current levels provide the best incentive for relatively long-term investments in agricultural technology. More generally, psychological factors can constrain investment in agricultural technology. Therefore, interventions that aim to alleviate these psychological constraints can be a valuable addition to popular agricultural policies (e.g, crop insurance, purchase contracts, provision of free/subsidized agricultural inputs, etc.). However, it is important to note that the existence of an inverted U-shaped relationship and behavior consistent with "aspirations frustration" highlights that raising aspirations by themselves could have a negative effect on psychological and economic well-being. As such, efforts to inspire increased investment in productivity-improving agricultural technologies may benefit from incorporating components that aim to alleviate both psychological and economic constraints.

Our findings suggest several directions for future work. First, our results highlight the importance of time horizons and payoff schedules when linking agricultural investments and aspirations. Future work might consider the role of psychological mechanisms related to time preferences, such as present bias and discount rates when assessing how aspirations influence different types of agricultural investments. Second, our results focus exclusively on income aspirations rather than treating aspirations as a multidimensional concept. Future work might use multidimensional aspirations to evaluate how agricultural investment decisions are influenced by aspirations in different domains.

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Supplemental Appendix to "Aspirations, Risk Preferences, and Investments in Agricultural Technologies"

This supplemental appendix includes the following additional tables and figures that support the analysis reported in the main manuscript.

- Figure A1 shows the provinces of Ecuador that together represent our study area.
- Figure A2 illustrates the visual guide provided to respondents when they participated in the prospect theory lottery games.
- Table A1 reports the raw correlation between each of our measured risk preference variables.
- Table A2 reproduces the results from Table 2 in the main manuscript but clusters the standard errors at the experimental session level, rather than at the canton level. Additionally, in specifications that include fixed effects, Table A2 includes experimental session fixed effects, rather than canton fixed effects.
- Table A3 reproduces some of the results from Table 2 in the main manuscript using an alternative representation of the elicited prospect theory risk preference parameters following the methods of (Liu, 2013).

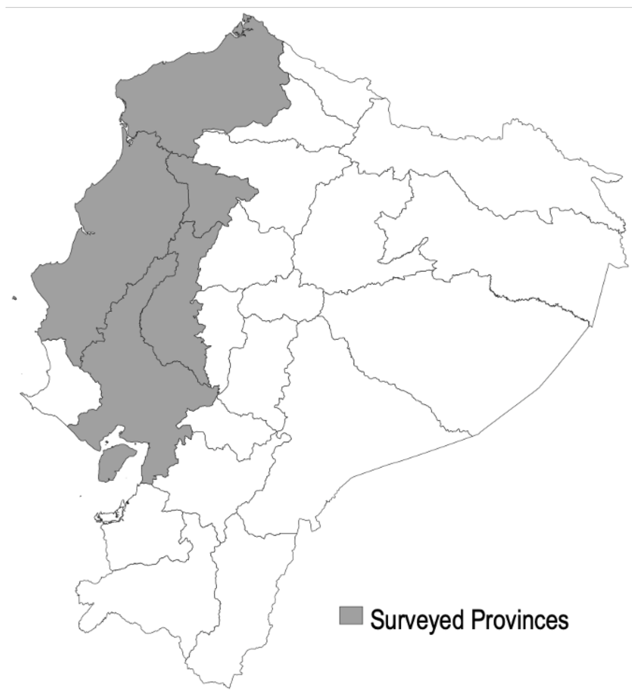

FIGURE A1: Study Area

Note: This figure illustrates the five coastal provinces of Ecuador that are part of the study area, namely, Esmeraldas, Guayas, Los Ríos, Manabí, and Santo Domingo de los Tsáchilas.

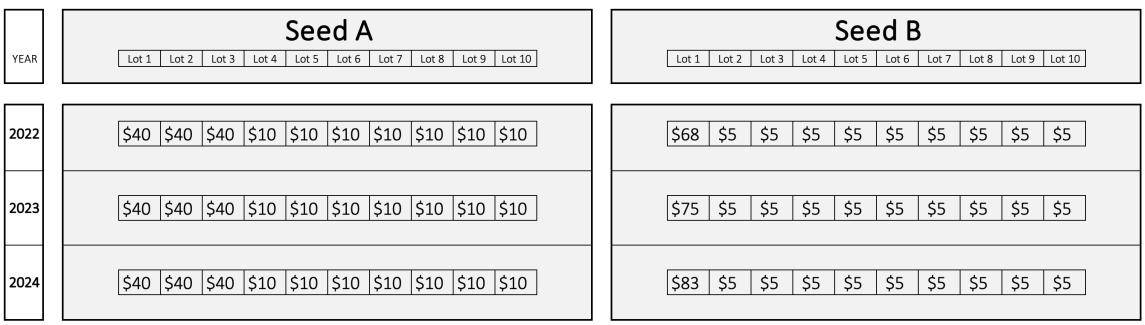

FIGURE A2: Lottery Representation of the Risk Experiment

Note: This figure illustrates the adaptation of the experimental design of Tanaka, Camerer and Nguyen (2010) developed by Villacis, Alwang and Barrera (2021).

TABLE A1: Correlation Matrix, Risk Preference Parameters

	(1) Dospert investing index	(2) PT risk aversion (σ)	(3) PT probability distortion (α)	(4) PT loss aversion (λ)
Dospert investing index	1.00			
PT risk aversion (σ)	0.043	1.00		
PT probability distortion (α)	0.049	-0.00	1.00	
PT loss aversion (λ)	-0.057	-0.46	0.014	1.00

Notes: This table reports the raw correlation between each of our risk preference parameters.

TABLE A2: Farm Renovation Expenditures, SEs Clustered at the Session Level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aspiration gap	2,608***			2,759***	2,244**	2,558***	2,026**
	(730.5)			(737.2)	(864.2)	(727.7)	(827.1)
Squared aspiration gap	-2,620***			-2,762***	-2,245**	-2,547***	-2,003**
	(673.7)			(681.1)	(831.1)	(667.6)	(788.5)
Dospert investing index		13.29**		14.11**	12.74		
		(5.714)		(5.686)	(8.495)		
PT risk aversion (σ)			-25.11			-23.29	-50.22
			(51.27)			(50.62)	(56.68)
PT probability distortion (α)			84.67			74.19	72.41
			(66.84)			(65.35)	(69.84)
PT loss aversion (λ)			-5.716			-5.014	-5.268
			(5.634)			(5.816)	(6.063)
Observations	523	523	523	523	523	523	523
R-squared	0.010	0.008	0.004	0.019	0.075	0.014	0.072
Session fixed effects?	No	No	No	No	Yes	No	Yes
Additional controls?	No	No	No	No	Yes	No	Yes
U-test results:							
Turning point	0.498			0.499	0.494	0.502	0.499
Fieller 95% CI	[0.414; 0.544]			[0.423; 0.545]	[0.329; 0.564]	[0.415; 0.551]	[0.295; 0.602]
Sasabuchi p-value	0.003			0.002	0.017	0.003	0.020
Slope at min	1,822.5			1,930.5	1,605.6	1,793.8	1,455.0
Slope at max	-1,792.7			-1,881.6	-1,612.6	-1,721.6	-1,418.6

Notes: This table reports ordinary least squares (OLS) regression estimates with total farm renovation expenditures as the dependent variable on the sub-sample of farmers with at least some farm renovation expenditures. The aspirations gap represents the difference between an individual's aspired monthly income and their current monthly income divided by their aspired monthly income. The Dospert investing variable represents a psychometric scale that assesses risk-taking in investment behavior. The risk aversion, probability distortion, and loss aversion variables are prospect theory risk preference parameters. Standard errors clustered at the experimental session level are reported in the parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A3: Farm Renovation Expenditures, Alternative Prospect Theory Parameter Values

	(1)	(2)	(3)	(4)
Aspiration gap	2,608***		2,613***	2,413**
	(630.1)		(600.0)	(1,032)
Squared aspiration gap	-2,620***		-2,607***	-2,339**
	(580.5)		(562.1)	(862.4)
PT risk aversion (σ)		0.193	-0.493	-28.10
		(43.37)	(44.77)	(50.64)
PT dummy for probability distortion ($\alpha < 1$)		-71.57	-66.82	-60.14
		(72.31)	(72.54)	(80.70)
PT dummy for loss aversion ($\lambda > 1$)		-5.556	-3.600	0.927
		(84.66)	(85.67)	(78.86)
Observations	523	523	523	523
R-squared	0.010	0.003	0.013	0.065
Canton fixed effects?	No	No	No	Yes
Additional controls?	No	No	No	Yes
U-test results:				
Turning point	0.498		0.501	0.516
Fieller 95% CI	[0.438; 0.536]		[0.450; 0.539]	[0.218; 0.576]
Sasabuchi p-value	0.001		0.001	0.021
Slope at min	1,822,5		1,830.8	1,711.5
Slope at max	-1,792.7		-1,766.7	-1,516.9

Notes: This table reports ordinary least squares (OLS) regression estimates with total farm renovation expenditures as the dependent variable. The aspirations gap represents the difference between an individual's aspired monthly income and their current monthly income divided by their aspired monthly income. The risk aversion, probability distortion, and loss aversion variables are prospect theory risk preference parameters. Standard errors clustered at the canton level are reported in the parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.