Why Not Insure Prices? Experimental Evidence from Peru

by Chris M. Boyd and Marc F. Bellemare

Why Not Insure Prices? Experimental Evidence from Peru

Chris M. Boyd♣ and Marc F. Bellemare*

June 30, 2021

Abstract

Farm revenue depends on volatile production and prices, but insurance efforts in developing countries have traditionally focused on covering production risk only. We run a lab-in-the-field experiment with farmers in Peru—wherein the only source of risk is uncertainty over the output price—to answer how insurance covering price risk affects production. Our results show that under price risk, without insurance, expected utility theory predictions—underproduction—does not hold at the extensive margin, although price risk causes underproduction when considering the magnitude of the risk. With compulsory price insurance at an actuarially fair premium, production is not significantly different than under price certainty, suggesting actuarially-fair insurance brings production back to certain price levels. Voluntary price insurance has large take-up rates when premiums are unsubsidized (70.8%), but—subsidized or not—price insurance, increases production over the certain price levels, suggesting the presence of moral hazard. Heterogeneous effects show no differential effects by farmer's selling position (i.e., being potato net-seller or net-consumer in real life), that moral hazard with voluntary insurance happens mostly among men, and that farmers without mechanisms to cope with low output price underproduce more without insurance and do not overproduce when offered either compulsory or non-compulsory price insurance.

JEL: C91, C93, D81, G52, Q14.
Keywords: Price insurance, price risk, price uncertainty, lab-in-the-field, Peru

♣ Corresponding author. Ph.D. Candidate in Applied Economics, University of Minnesota. email:boydl001@umn.edu
* Northrop Professor, Department of Applied Economics, University of Minnesota.

1. Introduction

Agricultural production is an inherently risky activity. Farm revenue depends on volatile production and price levels, but insurance efforts have traditionally focused on covering production risk, disregarding price risk.[1] In developed countries, production risk has been mitigated using crop insurance and subsidies, while price risk has been handled using exchange commodity boards, futures, and other financial market instruments. Nonetheless, in developing countries, farmers most of the time face production risk and price risk without any mitigation tools available, and the few insurance products have focused only on covering production risk.[2,3]

In the expected utility theory (EUT) framework, it is expected that price risk affects the levels of production. In his seminal paper, Sandmo (1971) found that under uncertainty risk-averse firms would produce less than under certainty. This claim has long been accepted in economics but, only recently, some papers have tested it empirically. For instance, Bellemare, Lee and Just (2020) found that underproduction under output price uncertainty does not always hold: in some cases, output price uncertainty is preferred to certainty, and risk-aversion does not seem to be an influencing factor. In this theoretical framework, insurance covering price risk would bring production levels back to the certain price levels, but this has not been tested empirically.

How does insurance covering price risk affect production? We answer this question by using lab-in-the-field experiments run with potato farmers in Peru. In a controlled scenario where only price risk exists,

[1] Farmers also face technological can policy risk (Moschini and Hennessy 2001).
[2] Agricultural and forestry insurance premiums looking to mitigate production risk are concentrated in the developed world; "Latin America and Asia account for 4 percent each, Central/Eastern Europe 3 percent and Africa just 2 percent" (Roberts, 2005). Price risk has been mitigated, for some crops, through commodity exchange boards, only in some African countries.
[3] Along this paper, price risk is defined as the uncertainty of prices with a known distribution. It is different from price ambiguity, which is defined as uncertainty of prices with an unknown distribution.

participants chose production levels in random certain and uncertain price rounds, when price insurance (offered at an actuarially-fair price) was compulsory and when it was voluntary and discounts (of 0%, 50% and 100% on the insurance premium) were offered. For comparison, participants also chose production levels in a baseline scenario where no insurance was offered. In sum, we aim to understand production behavior under output price risk given the presence of price insurance, and to recommend how this insurance should be implemented: compulsory or non-compulsory, and if so with or without subsidies.

Although insurance is the theoretical solution to risk problems, real world agricultural insurance is not widely adopted.[4] Agricultural microinsurance schemes based on—usually complex—rainfall, yield or other indices usually insure the quantity produced but not the output price, thus they do not fully insure farm revenue. These schemes have shown very low take-up rates, regardless the efforts for offering low premiums, addressing trust, liquidity constraints, offering financial literacy, among others (Platteau, De Bock, and Gelade 2017; Carter et al. 2017), leaving farmers in a similar situation to the absence of insurance markets.[5] Our analysis addresses what would happen to take up—and production—if we insure instead the price component of farm revenue, which can be a more understandable and trustable insurance index than previous indices used in microinsurance (Cole *et al.*, 2013).

The effects of insurance covering production risk on production—and investment in inputs—have been found to be positive in general. Using a framed game with farmers in Ethiopia, Hill and Viceisza (2012) find that in the presence of rainfall-index insurance, farmers purchase more fertilizer (29% more likely to buy an additional bag). Field experiments (RCTs) involving rainfall-index insurance have surprisingly found different results. Karlan *et al.* (2014), for farmers in Ghana, find that insurance increased the total farm costs (investment) in around 12%, although the value of total production was not affected, while cash

[4] This paper focuses on the developing countries case.
[5] In the absence of formal insurance markets, farmers rely on informal insurance schemes which can reduce the take up of new formal microinsurance products when both cover the same type of risks: covariate or idiosyncratic (Mobarak and Rosenzweig, 2013).

grants had relatively small effects. In contrast, Wong *et al.* (2020), for farmers in Ethiopia, find that subsidized insurance bundled with (small amount) input vouchers did not have a significant impact on fertilizer purchases or the total cost of inputs, while the (larger amount) input vouchers did. Moreover, Cole, Giné and Vickery (2017), for farmers in India, find that insurance did not have an impact on inputs investment, but it did on farmers switching to cash crops (12% increase)—with higher returns but more sensitive to deficient rainfall—and on inputs investment for those crops (10% increase in the value of inputs). For a hybrid rainfall-yield index insurance offered to Bangladeshi rice farmers, Hill *et al.* (2019) find a 16% increase of input expenditures, but not on production or yields. For a cost-of production insurance for corn farmers in the Philippines, He *et al.* (2020) find, as well, increases in fertilizers and total chemical expenditures.

The less studied compulsory insurance schemes also seem to have positive impacts on production, but they might have some problems. For an individual (non-indexed, compulsory, and 67% subsidized) insurance offered to Chinese tobacco farmers, Cai (2016) finds an increase of the insured production of tobacco by around 16%, compared to the scenario without insurance (and price uncertainty).[6] Using the Balloon Analogue Risk Task in an online experiment, Zhang and Palma (2020) find that compulsory insurance brings significant moral hazard but not adverse selection, and that it is the insurance type with the lowest social earnings—compared to voluntary or mixed insurance. Platteau, De Bock and Gelade (2017) warn that (state-directed) compulsory insurance may not reach people in the informal sector (for whom paying premiums is not enforceable) and it may lead to governance problems, but also call for more research on the respective roles of state and private insurance.

The narrow literature on insurance covering price risk has focused on analyzing its demand—willingness to pay (WTP)—rather than its impacts on production, but find that a price insurance would have a large

[6] Offering index insurance is cheaper than regular insurance because it is a pooled scheme—where everyone getting the insurance gets paid an indemnity or not—and there are not of verification at the individual level.

demand and would be commercially-viable. Sarris (2002), using data from Ghanaian cocoa farmers, finds that the WTP for price insurance is larger than the actuarially fair prices and larger than the actual prices of cocoa put options in the New York Board of Trade. For coffee farmers in Uganda, Hill (2010) estimates that the price risk has a substantial impact on welfare, such that most farmers will demand price insurance at actuarially fair premiums. For cocoa farmers in Cote D'Ivoire, Kouame and Komenan (2012) find that price is cited as the most important source of risk, and that two thirds of farmers were interested in taking up insurance, although the WTP for price insurance was relatively low (between 8.5% and 13.4% of percent of the option value they will receive). Moreover, using a choice experiment, in Gujarat (India), Ranganathan, Gaurav and Singh (2016) find that price insurance demand can be different depending on the type of crop: cotton (a cash crop) farmers value price insurance more than paddy (food crop) farmers.

Our paper has four main contributions. First, we analyze for the first time, with experimental data (where only price risk exists), the impacts of mitigating (insuring) price risk on production. By doing this, we also test the predictions of expected utility theory for price risk. Second, we measure the demand for subsidized and unsubsidized price insurance in our experimental setting. This provides a new way to measure the demand for price insurance, which we can compare to the previous literature findings—high demand for price insurance—, and the take-up of index microinsurance in developing countries. Third, our experimental setting allows to suggest whether price insurance should be implemented with or without subsidies, and in a compulsory or a voluntary manner; scenarios that have not been compared in the same setting before (Boyd and Bellemare, 2020). Our results allow to suggest which one of these scenarios is the most convenient in terms of achieving the levels of production under price certainty. Finally, we provide external validity to testing the Sandmo's prediction—underproduction when price uncertainty is present—by using a similar experiment to Bellemare, Lee and Just's (2020) as our baseline price risk scenario without insurance. While Bellemare, Lee and Just (2020) run their experiment in the lab with students in the United States and with (48) farmers in the field in coastal Peru, we run our experiment with a larger sample (101) of farmers in the Northern Andes of Peru. Participants in our experiment are potato farmers without access to any kind of agricultural insurance.

The results of our baseline experiment scenario—without insurance (game I)—support Bellemare, Lee and Just's (2020) findings that Sandmo's (1971) theory—underproduction under price risk—does not hold, neither for risk-averse agents nor for the full sample. Nonetheless, unlike them, we reject Batra and Ullah's (1974) prediction—that given price uncertainty, more price risk decreases production. In our second scenario—with compulsory and actuarially-fair output price insurance (game II)—we find no significant evidence that production levels under certain price are different than under price risk and compulsory insurance. These results suggest the EUT prediction—that actuarially-fair insurance brings production back to certain price levels—holds. Results from our experiment with voluntary price insurance (game III) show, first, that the demand for insurance is large—even when it is not subsidized (70.8%)—; larger than for microinsurance products.[7] Second, we find production increases under voluntary insurance and random premium discounts compared to production under price certainty, which suggest the presence of moral hazard. Moreover, production increases even more with risk-aversion, with riskier price distributions, and with a 100% premium discount. Exploring heterogeneous effects, we find no differential effects (in the three games) by the subject's selling position (i.e., being potato net-seller or net-consumer in real life) (Finkelshtain and Chalfant, 1991, 1997). We find no differences by gender without insurance, nor with compulsory insurance; but our results for voluntary insurance suggest men—by being less risk-averse—might be driving most of the moral hazard—overproduction—result. Interestingly, we find farmers without mechanisms to cope with low output price in real life (Mobarak and Rosenzweig, 2013) are more affected by price risk (Sandmo's prediction holds for them), and do not overproduce—incur in moral hazard—when offered either compulsory or non-compulsory price insurance. Towards policy-making, our results suggest

[7] Price insurance has a more familiar, trustable, and understandable index (price) and covers a non-catastrophic event (price volatility), unlike rainfall index microinsurance schemes.

implementing compulsory price insurance schemes, at an unsubsidized actuarially-fair premium, would protect farmers against price risk and avoid moral hazard.

In the following section, we describe the theoretical framework of the experiment, and the subsequent expected results. The third section details the design of the experiment. Section four comprises a description of the data, including how subjects are selected and their demographics. The fifth section describes the econometric strategy used to answer the research question. The sixth section summarizes the results. Section seven concludes.

2. Theoretical framework

To show that there exists underproduction in the presence of output price uncertainty, first, we borrow the theoretical framework used in Sandmo (1971). This corresponds to the first part of our experiment (Game I). Then, we develop a simple extension of insurance to the results derived by Sandmo (1971) to show that, in a context of output price uncertainty, with compulsory (i.e., full take-up) insurance the production should be higher than under uncertainty without insurance, but smaller than the production under output price certainty. This corresponds to the second part of the experiment (Game II). Finally, we generalize the framework for Game II to derive the results in the case of non-compulsory insurance (Game III).[8]

Proposition 1. Under output price risk, a risk-averse agent produces less output than under output price certainty.[9] In the framework of the expected utility theory, assume a risk-averse agent will maximize the following:

$$\max_{x} E[u(px - c(x) - F)] \tag{1}$$

[8] Proofs for propositions in this section can be provided by request.

[9] This proposition follows Sandmo (1971).

where $u(.)$ is the producer's utility function over profit $\pi = px - c(x) - F$, x is the output level, p is the realized output price ($p > 0$), $c(x)$ is a convex and increasing cost function (i.e. $c(0) = 0$, $c'(x) > 0$ and $c''(x) > 0$), and F is a fixed cost ($F > 0$).

After some derivations, we find that the marginal cost is smaller than the marginal benefit ($c'(x) < \mu$) of producing x, since marginal utility is always positive. Thus, under output price uncertainty, a risk-averse agent will produce less x than under output price certainty.

It is important to note that a risk-neutral or a risk-lover producer would benefit from price uncertainty, and thus produce more x than a risk-averse producer. As Baron (1970) finds with a similar framework: the optimal level of production is a nonincreasing function of the producer's risk aversion.[10] A risk-neutral producer would producer at the optimal level ($c'(x) = \mu$), but a risk-loving one would producer more than the optimal level ($c'(x) > \mu$).

Proposition 2. Under output price risk and a compulsory and actuarially fair output price insurance, a risk-averse agent produces the same output than under output price certainty.

Assume an insurance market scheme that covers producers against low output prices. In this scheme, k is the actuarially fair price of the insurance (i.e., insurance premium) per unit of x, and d is the realized indemnity per insured unit of x. Thus, the expected indemnity per insured unit of x (δ) is equal to the actuarially fair premium (k). Insured producers would receive d per unit of x produced only if the realized output price (p) goes below a given threshold, in this case, the expected output price (μ). Specifically, the indemnity received (d) is equal to the difference between the expected output price and the realized output

[10] Baron (1970) and Sandmo (1971) use an expected utility framework, and a von-Neuman Morgensten utility function. The profit function used by Baron (1970) does not include a fixed cost term, unlike Sandmo's, but this does not lead to any changes in the results.

price $(\mu - p)$ when the realized price is above or equal to the threshold $(p \geq \mu)$, and equal to zero when the realized price is below the threshold $(p < \mu)$.

Building on the previous scenario with price uncertainty, after multiple derivations, we find that under this compulsory full-insurance scheme, the risk-averse producer will maximize:

$$\max_{x^I} E[u(px^I - c(x^I) - F + (d-k)x^I] \quad (7)$$

Thus, $c'(x^I) + k = \mu + \delta$, which means the marginal cost of producing x under actuarially fair output price insurance is equal to the marginal benefit. ■

Proposition 3. Under output price risk and a voluntary and actuarially fair output price insurance, a risk-averse agent produces the same output than under output price certainty.

Risk-averse producers will buy the insurance if the expected utility from profits with insurance exceeds the expected utility of profits without insurance. In other words, the risk-averse producer will maximize either with or without insurance:

$$\max_{x,x^I} \{E[u(px - c(x) - F]; E[u(px^I - c(x^I) - F + (d-k)x^I]\} \quad (16)$$

From Propositions 1 and 2, we know that more will be produced under insurance $(x^* < x^{*I})$, and that since the insurance is actuarially fair $(k = \delta)$, equation (16) can be expressed as:

$$\max_{x,x^I} \{E[u(px^* - c(x^*) - F]; E[u(px^{*I} - c(x^{*I}) - F]\} \quad (16')$$

Given that expected utility is an increasing function of x, the expected utility with insurance will be larger than the expected utility without insurance. Thus, the risk-averse producer will choose to maximize production under insurance, insuring all her produced units. In other words, she will always prefer to purchase insurance when it is available, and she will produce more x (the same than under price certainty) in this framework than without insurance.

3. Experimental design

Our experiment aims to describe the behavior of participants (i.e. output choices) under output price risk and insurance, in controlled settings that simulate the theoretical framework (section 2). The experiment consists of five sections. The first three are game sets where participants have to choose the output levels and whether to purchase insurance.[11] The fourth is a risk elicitation lottery. The last one is a questionnaire. We randomized the order of the three game sets and the risk-elicitation lottery to avoid order effect bias.

Before participating in the experiment, enumerators made sure potential participants were potato farmers and sold at least part of their potato production in the market. Potential participants had to respond correctly two out of three basic math screening questions to make sure they could understand the games.[12] After passing this screening, participants read and signed the consent form, where it was stated that they would receive a minimum (fixed) amount of 40 PEN for their participation if they completed the experiment, as well as the maximum amount they could gain from their participation in the experiment. Then, for each participant, an additional compensation was randomized (from 1 to 10 PEN). This allows to test the presence of a house-money effect, i.e. whether a different fixed payoff will affect their behavior at choosing production levels.[13] Thus, participants' minimal compensation will range from 41 to 50 PEN. Subsequently, enumerators randomized the order of the game sets I, II and III, and then the order of the risk-elicitation game (i.e. lottery), which was played either before or after the three games. Participants played the game sets and lottery in a randomized order, but questionnaire was always responded at the end. Hereafter, we

---

[11] Participants have to choose the quantity produced, assuming production is certain, and that the cost function is increasing ($C(x) = 2(x^{1.4}) + 15$).

[12] The three questions were: 1. What is the 40% of 100 PEN? 2. If there is 25% of probability of rain, what is the probability that it does not rain? 3. Imagine there is bag with 3 blue balls and 7 red balls, which is the probability of choosing a blue ball?

[13] Moreover, adding a non-stochastic compensation might have helped getting a more realistic (less risk-averse) sample (Harrison, Lau and Elisabet Rutström, 2009).

describe the relevant aspects of the five sections of the experiment. The entire experiment protocol can be found in the Appendix section.

3.1. Game I: Production under output price risk without insurance

Game I replicates the output price risk game studied by Bellemare, Lee and Just (2020) with a few twists. In this game, participants played having only one task: choosing a production level (units of a single commodity) ranging from 0 to 20 (integers only), under two scenarios: (i) when the price per unit produced is certain and equal to 7 PEN, and (ii) when the price per unit produced is unknown, but participants know it can be equal to 5, 6, 7, 8 or 9 PEN. The unknown price could take four different price distributions, with different standard deviations (0.8, 1.17, 1.45, and 1.58), but the same mean price (7 PEN). In each round with uncertain price, only one price distribution was used, and it was known by the participant before she chose a production level. Certainty and uncertainty rounds were randomly alternated; the certainty game type occurred with 1/3 probability, and the uncertainty type game occurred with 2/3 probability.

Note that our lab-in-the field experiment design differs from the one by Bellemare, Lee and Just (2020) run in Peru in the following aspects. First, we did not frame the experiment commodity as “wheat” or “potato”, like they did, but as a “commodity” in general. Second, instead of using a “10 kg bag” as the unit of production, like they did in Peru, we used “arrobas” (equivalent to 11.4 kg), which is the usual measure when selling potatoes and other crops in the study area. Third instead of offering a fixed base compensation amount of 45 PEN, like they did in Peru, we offered participants a fixed base compensation of 40 PEN and a random additional amount that ranged from 1 to 10 PEN. Fourth, we used the Eckel and Grossman (2002) approach to elicit risk aversion, instead of the Holt-Laury approach that they used.[14]

[14] The Eckel and Grossman method has been proved to work better among individuals with low math abilities, which we can expect from the subjects in our experiment, but it has the issue that it cannot differentiate among higher levels of risk-seeking (Charness, Gneezy and Imas, 2013). Similarly, Crosetto and Filippin (2016) suggest that the Holt-Laury method of risk elicitation might be troublesome when subjects’ numeracy is an issue.

Profits in each round are calculated with the following function:

$$\pi = px - c(x) - F = px - 2x^{1.4} - 15 \tag{17}$$

where p is the realized price. Profits from each round under uncertain price were realized after the round price was realized. Subjects were given tables and figures that represent in a simple manner which will be their round profits under every output level and price, so they could guide their decisions. To make instructions clear, participants played first ten rounds of practice games, and then twenty rounds of real games, in which participants' final payoff was based.

To test output price risk only, our game did not allow other types of uncertainty (e.g., production uncertainty, input costs uncertainty, etc.). Besides, for simplicity, our setup did not allow storage, there were not survival constraints, and there was independence of rounds (i.e., one round's payoff does not affect other rounds' payoffs) and subjects (i.e., subjects decisions do not affect each other). At the same time, similarly to Bellemare, Lee and Just (2020), participants started every round with a base payoff of 25 PEN to eliminate liquidity constraints.

3.2. *Game II: Production under output price risk and compulsory insurance*

This game had exactly the same structure as the previous uncertainty game, except that with the mandatory insurance the profit function becomes:

$$\pi = (p)x - c(x) - F + (d - k)x \tag{18}$$

This is a full-insurance scheme, i.e., all quantity produced must be insured.[15] The insurance premium per unit (k) for the experiment was calculated as an actuarially fair insurance, and it was equal to 0.30 PEN.[16] The insurance indemnity per unit (d) takes the value of \$2 if the realized price is equal to \$5, or \$1 if the

[15] Notice that in the expected utility theory framework, if insurance is actuarially fair, the producer insures completely (Mas-Colell, Whinston, and Green 1995: 187-188). In this sense, Game II provides an incentive to behave as if participants were expected utility maximizers.

[16] Actuarially fair insurance premium was calculated as the price of the expected loss per unit produced. Given that participants face four different price distributions, the corresponding actuarially fair insurance premiums will be different. To simplify, we chose for all cases the smallest actuarially fair premium.

realized price is \$6. In other words, the compulsory full-insurance insures the output price only when it falls below the average price, and equates it to the average price (\$7). If the realized prices are \$7, \$8 or \$9, the insurance premium (k) is paid for all units produced, but the indemnity (d) is equal to zero. As such, the presence of compulsory insurance makes the variance of profits smaller. To make sure participants understood the instructions of this game, they first played ten rounds of practice, and then twenty rounds of real games.

Also notice two relevant issues related to the microinsurance literature. First, using this controlled setting allows to avoid the presence of informal insurance schemes that could also cover covariate risks, like the one this insurance covers (Mobarak and Rosenzweig, 2013). Second, as in Game I, all participants have a base payoff of 25 PEN to start every round of Game II. This also allows to eliminate liquidity constraints, which are considered in the microinsurance literature as one of the reasons why microinsurance is not extensively purchased.[17]

3.3. *Game III: Production under output price risk and insurance choice*

In Game set III participants chose whether to purchase insurance and the level of production, consecutively. Participants were randomly offered 0%, 50% of 100% discounts—with probability 1/3 each—on the actuarially fair insurance premium (0.30 PEN), after knowing if the output price was certain or uncertain, and the distribution of price. Output price and round payoff were realized after participants choose to purchase insurance and their production levels. Note that participants choosing to purchase insurance had to insure all their production.

[17] Although the base payoff (25 PEN) is the same for everyone, the compensation for participating in the experiment is randomized between 41 and 50 PEN—to measure the house money effect—, so we assume that the liquidity constraint is related to the base payoff and that the participants do not mentally account the compensation as part of their liquidity (Thaler 1985).

Thus, the profit from this game is equal to the profit of Game I if the participant chooses not to purchase insurance:

$$\pi = (p)x - c(x) - F \qquad (17)$$

The profit is equal to the profit of Game II if the participant chooses to buy insurance and if she is assigned a 0% discount on the premium per unit in Game III:

$$\pi = (p)x - c(x) - F + (d - k)x \qquad (18)$$

The profit when buying insurance and a 50% discount is:

$$\pi = (p - 0.5k + d)x - c(x) - F \qquad (18')$$

and the profit when buying insurance at a 100% discount is:

$$\pi = (p + d)x - c(x) - F \qquad (18'')$$

Participants played ten rounds of practice games to make sure they understood this game, and then twenty rounds of real games.

Note that the insurance offered in Game III is not a pooled microinsurance, but it has an important characteristic of those schemes: a company offering the output price risk insurance does not need to check every farmer’s losses, but only the price level, which is usually publicly available, easy to access, understandable and reliable—unlike some microinsurance measures like rainfall or yield indexes—. Nonetheless, our experiment assumes there are not transaction costs, that every farmer is a price taker, and that the realized (announced) price received by every farmer will be the same.

3.4. Risk elicitation lottery

Since Sandmo's (1971) theoretical predictions hold for a risk-averse agent, it is necessary to measure the level of risk aversion of each participant. Here, we use a modified version of the Eckel and Grossman (2002) game, using the maximum profit at the average price ($7) as a certainty reference point, i.e. $4.76. Participants were shown only the first four columns of Table 1, and they had to choose only one of the five lotteries. Risk (i.e. the risk level) is measured as the standard deviation of the expected payoffs, and the Constant Relative Risk Aversion (CRRA) coefficient R is calculated using the utility function ($U(x) = x^{1-r}/(1-R)$, where x is the payoff) proposed by Eckel and Grossman (2008).[18]

Table 1. Eckel and Grossman Risk Elicitation Game

Gamble choice	**Event**	**Probability (%)**	**Payoff**	**Expected Payoff**	**Risk**	**CRRA ranges**
1	A	50	4.76	4.76	0.00	$R > 2$
	B	50	4.76			
2	A	50	7.14	5.36	1.79	$0.67 < R < 2$
	B	50	3.57			
3	A	50	9.52	5.95	3.57	$0.38 < R < 0.67$
	B	50	2.38			
4	A	50	11.90	6.55	5.36	$0.20 < R < 0.38$
	B	50	1.19			
5	A	50	14.28	7.14	7.14	$r < 0.20$
	B	50	0.00			

3.5. End of experiment questionnaire

This questionnaire included potential control variables for the estimated regressions. It included sociodemographic and household questions (age, sex, ethnicity, household size, economic activities), farm-related questions (planted crops, importance of potato, net consumption of potato, price of potatoes, farming experience, credit), geolocation, and two context questions (hunger and satisfaction with weather).

4. Data and Descriptive Statistics

[18] The modified payoffs of our lotteries allow us to obtain the same CRRA coefficients as Eckel and Grossman (2008). The CRRA used in the regressions correspond to 2 for lottery 1, 0.2 for lottery 5, and the mid-value of the CRRA range for the remaining lotteries.

Our data come from lab-in-the-field experiments conducted individually with 101 potato farmers (mainly food crop farmers) in the region of Cajamarca, Peru, in August 2019. Each farmer played 10 rounds of practice games, and 20 rounds of real games for each one of the three game sets described in section 3. We focus on the real rounds only, thus for each one of the three game sets, we use a sample of 2,020 observations. The experiments were conducted in the districts of Cajamarca that had the most potato farmers according to the most recent data of the Ministry of Agriculture.[19] Subjects were personally invited to participate in the experiment, in the villages where they lived or worked.[20]

Table 2 presents summary statistics at the round level, for each one of the three game sets, and characteristics at the subject level. Stats at the round level (Panel A) show that price and price risk were strictly randomized in the three game sets: price was on average 7 PEN, two thirds of the rounds had uncertain prices, and in those rounds the four different price distributions (scenarios 1, 2, 3 and 4) occurred similar number of times (around 16.7% each one). Similarly, for the third game set, insurance premium discounts (of 0%, 50%, and 100%) were offered randomly, a third of the time each in uncertain price rounds (around 22.2% each one), as designed. On average, participants chose to produce around 10.3 units in certain rounds of each game, when the optimal level was 10, showing that the game was in general well understood. The distribution of output choices is shown in Figures 1-6 in the Appendix.

Table 2. Summary statistics

Panel A. Round-level variables	***Game I***	***Game II***	***Game III***
Uncertain price rounds (1=Yes)	0.657	0.674	0.666
	(0.475)	(0.469)	(0.472)
Price distribution 1 (1=Yes)	0.168	0.167	0.167
	(0.374)	(0.373)	(0.373)

[19] At the time of the experiment, most of these districts were also among the poorest districts of Peru, and Cajamarca was the poorest region of Peru.

[20] To avoid communication between farmers about the experiment, all enumerators worked at the same time with farmers of the same village. Moreover, each enumerator worked with no more than two farmers per village if they were small villages, or with farmers living far from each other if villages were large. No experiments were conducted in the same village in more than one day. Thus, farmers were not randomly selected to participate in the experiment. Nonetheless, this should have not affected the distribution of risk attitudes in the sample (Harrison, Lau and Elisabet Rutström, 2009).

Price distribution 2 (1=Yes)	0.159	0.151	0.159
	(0.366)	(0.359)	(0.366)
Price distribution 3 (1=Yes)	0.174	0.161	0.177
	(0.379)	(0.368)	(0.382)
Insurance offered at 0% discount (1=Yes)	--	--	0.215
			(0.411)
Insurance offered at 50% discount (1=Yes)	--	--	0.215
			(0.411)
Insurance offered at 100% discount (1=Yes)	--	--	0.236
			(0.425)
Price distribution 4 (1=Yes)	0.156	0.194	0.163
	(0.363)	(0.396)	(0.369)
Output choice in certain rounds	10.266	10.307	10.253
	(2.660)	(2.379)	(2.286)
Output choice in uncertain rounds	10.170	10.392	10.802
	(3.721)	(3.197)	(3.229)
Output choice if purchased insurance	--	--	10.929
			(3.125)
Purchased insurance at 0% discount (1=Yes)	--	--	0.708
			(0.455)
Purchased insurance at 50% discount (1=Yes)	--	--	0.809
			(0.394)
Purchased insurance at 100% discount (1=Yes)	--	--	0.941
			(0.236)
Observations (rounds)	2,020	2,020	2,020
Subjects	101	101	101

Subject-level statistics (Panel B of Table 2) show that the risk-elicitation lottery was played at the end of the three game sets for 53.5% of subjects. The risk-aversion derived from this lottery was on average 0.738 (in a scale from 0.2 to 2, where 2 is the CRRA value for most risk-averse individual). The randomized additional compensation (from 1 to 10 PEN), aimed to measure the house-money effect, was on average 5.82 PEN.

From the final questionnaire, we also know potato farmers in our sample live in remote rural areas, not well-connected to the markets, depend heavily on agriculture, and have little access to financial services that can help them cope with risks associated with agricultural activities. Nonetheless, these farmers face large price variation: on average, the worst potato price they received was 5.02 PEN—same as the minimum price in our experiment—and the best was 15.96 PEN—while our maximum price was 9 PEN.

Table 2. Summary Statistics (continued)

Panel B. Subject-level variables	***Mean***	***SD***
Risk-aversion (CRRA)	0.738	0.633
Eckel-Grossman lottery played after the 3 games (1=Yes)	0.535	0.501
Additional random compensation for participation (1-10 PEN)	5.792	2.546
Feel hungry (1=Yes)	0.168	0.376
Weather preference (min 1- max 10)	7.614	2.222
Age	38.505	13.057
Sex (1=male)	0.624	0.487
Years of education	6.812	3.236
Indigenous, mestizo or non-white (1=Yes)	0.812	0.393
Altitude (m.a.s.l.)	3381.366	217.575
Distance to the closest market (hours)	1.181	0.948
Household income from agriculture (%)	48.663	25.168
Number of crops planted by the household	3.822	2.151
Potato monocropping (1=Yes)	0.149	0.357
Number of potato varieties planted	2.455	1.229
Potato area (ha)	0.475	0.593
Potato harvest for self-consumption (%)	38.853	19.941
Years cultivating potato	16.733	12.671
Best price of potato ever received, per arroba	15.960	6.025
Worst price of potato ever received, per arroba	5.025	2.728
Price of potato received last season, per arroba	11.188	5.061
Number of small animals	16.495	17.379
Number of big animals	4.762	3.858
Currently has a credit (1=Yes)	0.109	0.313
Has had non-health insurance (1=Yes)	0.030	0.171
Observations (subjects)	101	

5. Empirical Strategy

For games I and II, to analyze the behavior of subjects (i.e., choices of production levels), we use a linear regression with subject-specific random effects and standard errors clustered at the subject level, given that the identifying variation (i.e., price risk expressed as uncertain price rounds and price distributions) is experimental, and thus orthogonal to the error term. Specifically, we estimate the following equation:

$$y_{it} = \alpha_1 + \beta_1 I(\sigma_t > 0) + \delta_1 R_i + \kappa_1 h_i + \tau_1 t_t + \theta_1 X_i + \nu_{1i} + \epsilon_{1it} \qquad (19)$$

where y_{it} is the output level chosen by subject i in round t, $I(\sigma_t > 0)$ is the treatment variable, a dummy variable that takes value of 1 if the round was an uncertainty type game and takes value of 0 if the round was a certainty type game, R_i is the Arrow-Pratt risk-aversion coefficient obtained from the Eckel and Grossman (2002) risk elicitation lottery (see section 3.4), h_i is the base compensation of the individual (ranging randomly from 41 to 50 PEN), t_t is the round order number (1-60), X_i is a vector of control variables at the individual level, coming from the end of experiment questionnaire, ν_{1i} is an individual-specific effect, and $\epsilon_{1it}$is the regression error. This equation allows to estimate the average treatment effect (ATE) of price risk on output without insurance (for game I) and with compulsory insurance (for game II), and thus test the expected utility theory predictions described in 2.1 (Sandmo, 1971) and 2.2.

For game III, we add the random discount of the insurance premium to (19). This model allows to obtain the average impact of price risk on production when price insurance is available, i.e., the intention to treat (ITT). Specifically, we estimate the following equation:

$$y_{it} = \alpha_2 + \beta_2 I(\sigma_t > 0) + \delta_2 R_i + \kappa_2 h_i + \tau_2 t_t + \theta_2 X_i + \nu_{2i} + \epsilon_{2it} \qquad (20)$$

In the following section we present the results of these estimations, which test the impact of price risk with and without insurance at the extensive margin. We also present alternative specifications using the standard deviation of price in each round (σ_t)—instead of only the dummy $I(\sigma_t > 0)$–and dummies for each one of the four price distribution scenarios to measure the impact of price uncertainty (with and without insurance) on production at the intensive margin. Furthermore, we perform all regressions for the whole sample of subjects, and the subsample of risk-averse subjects, defined as such by their choices in our—Eckel and Grossman (2002) type—risk-elicitation lottery.

Equations (19) and (20) allow to accurately estimate the impact of price risk on production under each of the three games (without insurance, with compulsory insurance, and with available insurance and premium discounts) since uncertain and certain rounds, price distributions, and insurance discounts occur randomly. Moreover, control variables at the individual level increase efficiency.

6. Results

We compare the results (production levels) of all three sets of games, assessing whether they follow the predictions from the expected utility theory presented in section 2. First, we present the results of production under price risk without output price insurance (Game I). Moreover, we compare our results to those of Bellemare, Lee and Just (2020). Then, we present the results of production under price risk and compulsory output price insurance (Game II). Finally, we present the results of production under price risk and available output price insurance (Game III) for the whole sample, and for the different premium discounts (0%, 50%, and 100%). For all cases, we present the results for the whole sample of subjects and for the risk-averse ones; at the extensive and intensive margins; and with and without covariates.

6.1. Estimation of production under output price risk (Game I)

As stated in the theoretical section, based in the expected utility theory framework, we expect that under uncertainty (Game I) the risk-averse agent will produce less than under certainty. Results for all subjects in Table 3 show that at the extensive margin (i.e., only considering a dummy for uncertain price round), with or without additional control variables (specifications (1) and (2), respectively), the impact of price risk on production is not significant. In other words, like for Bellemare, Lee and Just (2020), our results do not support Sandmo's prediction. At the intensive margin (i.e., defining price risk as the standard deviations of the uncertain price distributions), we find no significant impacts of price risk on production either.

In specifications (5) and (6), we include price risk variables at the extensive and intensive margins, with and without controls. We find that, given the presence of price risk (uncertain price round dummy), increasing price risk (standard deviation), results in an increase of production, opposing Batra and Ullah's (1974) prediction and Bellemare, Lee and Just's (2020) findings. Specifically, price risk at the extensive margin decreases production in 1.38 units, and price risk at the intensive margin increases production in 0.98 units per additional standard deviation of the price distribution. In other words, farmers produced less in uncertain rounds than in certain rounds—as expected utility theory predicts—, but among uncertain rounds they produced more when the standard deviation of price was larger. Moreover, using dummies for each of the four price distributions assigned randomly, in specifications (7) and (8), we find that only the price distribution of the first scenario—with the smallest standard deviation—has a negative and significant impact on production, suggesting the behavior in response to price risk is not continuous and nonmonotonic (Bellemare, Lee and Just, 2020). Note that in all the specifications in Table 3 the coefficient of risk-aversion was not significant. Moreover, the randomized additional compensation was not significant either, rejecting the presence of a house-money effect.[21]

Results for the subsample of risk-averse subjects are presented in Table 4.[22] Results are very similar to those in Table 3 for the full sample: there is not significant impact of price risk on production at the extensive or intensive margins (specifications (1) to (4), and point estimates for specifications (5), (6), (7), and (8) have the same sign and are larger than those for the full sample. Note that risk-aversion and the additional compensation are no longer significant. Moreover, all our results for game I remain significant when using randomization inference.

[21] Notice that the house-money effect does not represent changes in liquidity constraints. Every round is independent, and subjects have 25 dollars at the beginning of every round.
[22] We define risk-averse subjects as those with a coefficient of risk-aversion larger than 0.5, i.e., those who chose lotteries 1, 2, or 3 in Table 1.

Table 3. Price Risk Effects on Production without insurance (Game I)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Output choice (0-20)							
Uncertain price round (1=Yes)	-0.170	-0.167			-1.248***	-1.234***		
	(0.201)	(0.203)			(0.434)†††	(0.437)†††		
Standard deviation of Price Distribution			0.009	0.010	0.866***	0.857***		
			(0.143)	(0.145)	(0.305)†††	(0.307)†††		
Price Distribution 1							-0.603**	-0.598**
							(0.243)†††	(0.245)†††
Price Distribution 2							-0.148	-0.145
							(0.295)	(0.299)
Price Distribution 3							0.015	0.027
							(0.250)	(0.249)
Price Distribution 4							0.074	0.061
							(0.268)	(0.272)
Additional random compensation for participation (1-10)	0.028	0.104	0.028	0.103	0.028	0.105	0.028	0.106
	(0.061)	(0.082)	(0.060)	(0.082)	(0.060)	(0.082)	(0.061)	(0.082)
Risk-aversion (CRRA)		-0.122		-0.127		-0.129		-0.129
		(0.270)		(0.268)		(0.269)		(0.268)
Round order number, as played		0.025		0.025		0.024		0.025
		(0.016)		(0.016)		(0.016)		(0.016)
Constant	9.144***	6.818	9.035***	6.780	9.157***	6.626	9.155***	6.562
	(0.463)	(4.298)	(0.464)	(4.308)	(0.456)	(4.312)	(0.456)	(4.331)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,020	2,020	2,020	2,020	2,020	2,020	2,020	2,020
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include: sex (1=male), age, years of education, altitude (m.a.s.l.), household income from agriculture (%), feeling hungry (1=Yes), weather preference (1-10), dependence ratio, number of big animals, number of small animals, years cultivating potato, potato area (ha), distance to the closest market (hours), indigenous (1=Yes), mestizo or non-white (1=Yes), family receives the CCT (1=Yes), number of economic activities done by the household, potato monocropping (1=Yes), potato harvest for self-consumption (%), number of crops planted by the household, number of potato varieties planted, currently has a credit (1=Yes), has had non-health insurance (1=Yes), when price is low, sells potato at the market price (1=Yes), and actual price of potato received last season.

Table 4. Price Risk Effects on Production without insurance (Game I), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Output choice (0-20)							
Uncertain price round (1=Yes)	-0.221	-0.216			-1.419**	-1.385**		
	(0.259)	(0.264)			(0.573) †††	(0.581) †††		
Standard deviation of Price Distribution			-0.015	-0.015	0.964**	0.940**		
			(0.187)	(0.191)	(0.414) †††	(0.420) †††		
Price Distribution 1							-0.747**	-0.732**
							(0.318) †††	(0.322)†††
Price Distribution 2							-0.052	-0.052
							(0.387)	(0.396)
Price Distribution 3							-0.208	-0.197
							(0.331)	(0.328)
Price Distribution 4							0.173	0.154
							(0.366)	(0.372)
Additional random compensation for participation (1-10)	-0.020	0.028	-0.018	0.030	-0.018	0.027	-0.017	0.026
	(0.085)	(0.105)	(0.085)	(0.104)	(0.085)	(0.105)	(0.085)	(0.105)
Risk-aversion (CRRA)		-0.197		-0.213		-0.214		-0.194
		(0.428)		(0.426)		(0.426)		(0.424)
Round order number, as played		0.025		0.025		0.024		0.024
		(0.019)		(0.019)		(0.019)		(0.019)
Constant	9.311***	9.319	9.209***	9.307	9.297***	8.869	9.320***	8.575
	(0.696)	(5.885)	(0.699)	(5.921)	(0.689)	(5.945)	(0.681)	(5.986)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3

6.2. Estimation of production under output price risk and compulsory insurance (Game II)

The results for Game II (Tables 5 and 6) show that under compulsory output price insurance, i.e., fixing the market failure, there is not significant impact of output price risk on production, not for the full sample not for the risk averse subjects. At the extensive (specifications (1) and (2)) and intensive (specifications (3) and (4)) margins, not only the effect of price risk on production is not significant, but the standard errors are smaller than in Game I, for the risk averse subsample and for the full sample. Specifications (5) and (6) show a significant increase of price risk on production, given that price risk exists, only when using randomization inference. The point estimates have the same sign than in Game I, but their magnitude and standard errors are smaller, for the full sample and the risk averse subsample.

Specifications (7) and (8), where price risk is expressed as dummies for each price distribution, also show no significant impacts of any of the price distributions on production, except for distribution 3, when using randomization inference for the full sample. Moreover, compared to Game I, for price distribution 1—with the smallest standard deviation—we find non-significant impacts, and smaller standard errors, for both the full sample and the risk averse subjects. In sum, we find no evidence of production increasing or decreasing—compared to certain price production levels—as a result of price risk when compulsory price insurance is in place.

Table 5. Price Risk Effects with compulsory insurance (Game II)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Output choice (0-20)							
Uncertain price round (1=Yes)	-0.013	-0.016			-0.365	-0.381		
	(0.164)	(0.165)			(0.365)†††	(0.365)†††		
Standard deviation of Price Distribution			0.033	0.033	0.278	0.288		
			(0.114)	(0.114)	(0.246)†††	(0.249)†††		
Price Distribution 1							-0.132	-0.140
							(0.207)	(0.206)
Price Distribution 2							-0.156	-0.162
							(0.240)	(0.239)
Price Distribution 3							0.318	0.327
							(0.214)††	(0.214)††
Price Distribution 4							-0.076	-0.081
							(0.212)	(0.217)
Additional random compensation for participation (1-10)	0.053 (0.049)	0.039 (0.062)	0.053 (0.049)	0.039 (0.062)	0.054 (0.049)	0.041 (0.062)	0.053 (0.050)	0.040 (0.063)
Risk-aversion (CRRA)		0.321		0.320		0.322		0.316
		(0.270)		(0.270)		(0.271)		(0.271)
Round order number, as played		0.007		0.007		0.007		0.008
		(0.011)		(0.011)		(0.011)		(0.011)
Constant	10.033***	9.702***	9.998***	9.656***	10.036***	9.655***	10.037***	9.592***
	(0.648)	(3.596)	(0.646)	(3.592)	(0.649)	(3.586)	(0.648)	(3.600)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,020	2,020	2,020	2,020	2,020	2,020	2,020	2,020
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 6. Price Risk Effects with compulsory insurance (Game II), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	-0.065	-0.063			-0.360	-0.378		
	(0.228)	(0.233)			(0.380)††	(0.383)††		
Standard deviation of Price Distribution			-0.008	-0.004	0.233	0.248		
			(0.154)	(0.158)	(0.226)†††	(0.231)†††		
Price Distribution 1							-0.291	-0.293
							(0.250)	(0.253)
Price Distribution 2							0.118	0.115
							(0.313)	(0.315)
Price Distribution 3							0.107	0.107
							(0.287)	(0.292)
Price Distribution 4							-0.155	-0.142
							(0.268)	(0.280)
Additional random compensation for participation (1-10)	-0.009	-0.002	-0.008	-0.002	-0.009	-0.001	-0.005	0.001
	(0.068)	(0.088)	(0.068)	(0.088)	(0.068)	(0.088)	(0.068)	(0.088)
Risk-aversion (CRRA)		0.716**		0.715**		0.717**		0.722**
		(0.359)		(0.359)		(0.359)		(0.359)
Round order number, as played		0.007		0.007		0.008		0.007
		(0.016)		(0.016)		(0.016)		(0.016)
Constant	11.364***	8.746**	11.319***	8.723**	11.363***	8.719**	11.339***	8.676**
	(1.765)	(4.303)	(1.766)	(4.300)	(1.771)	(4.283)	(1.773)	(4.306)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

6.3. *Estimation of production under output price risk and available insurance (Game III), and insurance demand*

Game III allows to measure the demand for output price insurance. Price insurance take-up was 70.8% at the actuarially fair premium—when no discount was offered. As expected, the take-up of the output price insurance increased with the premium discounts: to 80.9% at 50% premium discount, and to 94.1% with 100% discount.[23] These take-up rates are large as some willingness to pay for price insurance studies predicted (Sarris, 2002; Hill, 2010; Ranganathan, Gaurav and Singh, 2016), and they are even larger than the largest rainfall index microinsurance take-up rates (Mullally, Boucher and Carter, 2010; Karlan *et al.*, 2014; Elabed and Carter, 2015; Platteau, De Bock and Gelade, 2017).

When output price insurance is available—and premium discounts are too—we find price risk increases production at the extensive and intensive margins (specifications (1) to (4)), for the full sample and the risk averse subsample (see Tables 7 and 8). For the whole sample, at the extensive margin, price risk increases production in around 0.42 units—at the 10% significance level and at the 1% with randomization inference. While, at the intensive margin, price risk (one more standard deviation of the price distribution) increases production in 0.32 units. We find similar results, but larger point estimates for the subsample of risk averse subjects. Nonetheless, when assessing the impact of increasing price risk, given the presence of price risk (specification (5) and (6)), we do not find any significant impacts on production, for the full and the risk averse subsample.

Including dummies for price distribution scenarios (specifications (7) and (8)), with randomization inference, we find that subjects increase their production—when price risk and price insurance are available—when faced with larger price standard deviations, instead of responding solely to scenario 1, like

[23] There is not full demand for price insurance at a 100% discounted premium, but the high take-up is even larger than what previous studies have estimated. For instance, Hill (2010) estimates an 80% demand for insurance when the premium is zero.

in Game I. Among the risk-averse subsample (Table 8), all price distributions increase production significantly, according to randomization inference, but the riskier price distribution (scenario 4) increases production even more.

To assess whether the price insurance premium discounts have different impacts on production, we compare the production in certain price rounds to the production in uncertain price rounds when no discount was offered (Tables 9 and 10), when 50% premium discount was offered (Tables 11 and 12), and when 100% premium discount was offered (Tables 13 and 14). Our results show that with or without offering premium discounts, the availability of insurance—at the extensive and intensive margins—increases, even more among the risk-averse subjects. Nonetheless, we find larger point-estimates at a 100% premium discount. In specifications (7) and (8), riskier price distributions seem to increase production more when the premium was discounted, even more among the risk averse subsample, although we do not find a monotonic behavior.

In appendix 2 (tables A.1 and A.2), we use the randomized discounts as an instrumental variable to measure the impact of purchasing insurance on production, i.e., the local average treatment effect (LATE) for those motivated by the discount to get the insurance. First-stage results show the instrument is relevant (F-stats larger than 10), and second-stage results show the additional demand for insurance does not significantly increase production over the certain price level for the full sample, nor for the risk-averse subsample. When restricting the sample to (62) subjects who understood the game better (tables A.3 and A.4), we do find significant increases of production due to the insurance purchase, suggesting that subjects self-selecting into buying the insurance due to the discount are probably those who are going to benefit more from the insurance. In sum, our results for game III suggest the presence of moral hazard when price insurance is non-compulsory, whether it is subsidized or not, which increases with the intensity of price risk and the degree of risk-aversion.

Table 7. Price Risk Effects with available insurance (Game III)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Output choice (0-20)							
Uncertain price round (1=Yes)	0.428*	0.417*			0.069	0.076		
	(0.230)†††	(0.230)†††			(0.343)	(0.343)		
Standard deviation of Price Distribution			0.330**	0.320**	0.286	0.272		
			(0.156)†††	(0.156)†††	(0.221)	(0.221)		
Price Distribution 1							0.234	0.225
							(0.247)	(0.246)
Price Distribution 2							0.596**	0.593**
							(0.273)†††	(0.274)†††
Price Distribution 3							0.401	0.397
							(0.272)††	(0.273)††
Price Distribution 4							0.532*	0.507*
							(0.283)†††	(0.282)†††
Premium discount (0%, 50%, or 100%)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Additional random compensation for participation (1-10)	-0.018	-0.004	-0.018	-0.003	-0.018	-0.003	-0.017	-0.001
	(0.053)	(0.059)	(0.053)	(0.059)	(0.053)	(0.059)	(0.053)	(0.058)
Risk-aversion (CRRA)		0.331		0.335		0.334		0.336
		(0.254)		(0.254)		(0.253)		(0.253)
Round order number, as played		0.015		0.015		0.015		0.015
		(0.012)		(0.012)		(0.012)		(0.012)
Constant	9.982***	14.503***	9.971***	14.426***	9.968***	14.429***	9.963***	14.412***
	(0.675)	(3.093)	(0.670)	(3.082)	(0.670)	(3.084)	(0.671)	(3.076)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,020	2,020	2,020	2,020	2,020	2,020	2,020	2,020
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 8. Price Risk Effects with available insurance (Game III), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	0.570*	0.575*			0.047	0.048		
	(0.304)†††	(0.302)†††			(0.447)	(0.452)		
Standard deviation of Price Distribution			0.451**	0.453**	0.421*	0.424		
			(0.197)†††	(0.196)†††	(0.255)	(0.258)		
Price Distribution 1							0.421	0.428
							(0.333)††	(0.332)††
Price Distribution 2							0.621*	0.633*
							(0.336)†††	(0.335)†††
Price Distribution 3							0.359	0.362
							(0.351)†	(0.349)†
Price Distribution 4							0.991***	1.005***
							(0.343)†††	(0.342)†††
Premium discount (0%, 50%, or 100%)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Additional random compensation for participation (1-10)	-0.045	-0.035	-0.042	-0.032	-0.042	-0.032	-0.045	-0.034
	(0.065)	(0.078)	(0.066)	(0.078)	(0.066)	(0.078)	(0.067)	(0.077)
Risk-aversion (CRRA)		0.374		0.365		0.366		0.391
		(0.327)		(0.326)		(0.328)		(0.327)
Round order number, as played		0.036**		0.036**		0.036**		0.036**
		(0.018)		(0.018)		(0.018)		(0.018)
Constant	10.814***	11.858***	10.760***	11.833***	10.759***	11.825***	10.741***	11.695***
	(1.703)	(3.755)	(1.692)	(3.701)	(1.693)	(3.707)	(1.664)	(3.721)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1 for statistical inference. ††† p<0.01, †† p<0.05, † p<0.1 for randomization inference. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 9. Price Risk Effects with available insurance and without premium discounts (Game III)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Dependent variable: Output choice (0-20)				
Uncertain price round (1=Yes)	0.545**	0.524**			-0.034	-0.039		
	(0.249)	(0.248)			(0.696)	(0.692)		
Standard deviation of Price Distribution			0.437**	0.421**	0.461	0.449		
			(0.192)	(0.193)	(0.547)	(0.548)		
Price Distribution 1							0.199	0.195
							(0.332)	(0.331)
Price Distribution 2							0.802**	0.752**
							(0.379)	(0.366)
Price Distribution 3							0.769**	0.753**
							(0.361)	(0.364)
Price Distribution 4							0.431	0.412
							(0.447)	(0.450)
Additional random compensation for participation (1-10)	0.005 (0.058)	0.003 (0.060)	0.007 (0.058)	0.006 (0.060)	0.007 (0.058)	0.006 (0.060)	0.009 (0.058)	0.010 (0.060)
Risk-aversion (CRRA)		0.305		0.306		0.306		0.291
		(0.271)		(0.271)		(0.271)		(0.271)
Round order number, as played		-0.002		-0.001		-0.001		-0.001
		(0.015)		(0.016)		(0.016)		(0.016)
Constant	10.252***	15.769***	10.235***	15.665***	10.235***	15.660***	10.243***	15.563***
	(0.614)	(3.267)	(0.607)	(3.256)	(0.607)	(3.248)	(0.608)	(3.235)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 10. Price Risk Effects with available insurance and without premium discounts (Game III), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	0.623*	0.666**			0.079	0.147		
	(0.329)	(0.330)			(0.913)	(0.915)		
Standard deviation of Price Distribution			0.494**	0.519**	0.437	0.414		
			(0.249)	(0.250)	(0.692)	(0.699)		
Price Distribution 1							0.428	0.484
							(0.443)	(0.446)
Price Distribution 2							0.630	0.673
							(0.506)	(0.494)
Price Distribution 3							0.607	0.605
							(0.455)	(0.464)
Price Distribution 4							0.868*	0.942*
							(0.527)	(0.536)
Additional random compensation for	-0.066	-0.045	-0.063	-0.041	-0.063	-0.042	-0.062	-0.041
participation (1-10)	(0.072)	(0.072)	(0.072)	(0.073)	(0.072)	(0.072)	(0.071)	(0.072)
Risk-aversion (CRRA)		0.813***		0.804**		0.806**		0.810***
		(0.313)		(0.316)		(0.314)		(0.310)
Round order number, as played		0.019		0.020		0.020		0.020
		(0.023)		(0.023)		(0.023)		(0.023)
Constant	10.933***	12.735***	10.866***	12.770***	10.870***	12.750***	10.850***	12.796***
	(1.243)	(3.374)	(1.219)	(3.348)	(1.216)	(3.346)	(1.187)	(3.348)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	671	671	671	671	671	671	671	671
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 11. Price Risk Effects with available insurance and with 50% premium discount (Game III)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	0.416**	0.412**			0.424	0.431		
	(0.190)	(0.192)			(0.670)	(0.672)		
Standard deviation of Price Distribution			0.303**	0.299**	-0.006	-0.015		
			(0.132)	(0.132)	(0.466)	(0.461)		
Price Distribution 1							0.470	0.454
							(0.340)	(0.345)
Price Distribution 2							0.266	0.272
							(0.296)	(0.299)
Price Distribution 3							0.606**	0.645**
							(0.265)	(0.267)
Price Distribution 4							0.330	0.283
							(0.301)	(0.295)
Additional random compensation for participation (1-10)	-0.027	-0.027	-0.027	-0.029	-0.027	-0.027	-0.026	-0.026
	(0.050)	(0.057)	(0.049)	(0.057)	(0.050)	(0.057)	(0.050)	(0.057)
Risk-aversion (CRRA)		0.371		0.368		0.371		0.367
		(0.231)		(0.230)		(0.231)		(0.232)
Round order number, as played		0.022		0.023		0.022		0.023*
		(0.014)		(0.014)		(0.014)		(0.014)
Constant	9.947***	12.436***	9.954***	12.526***	9.947***	12.434***	9.941***	12.402***
	(0.515)	(2.797)	(0.515)	(2.783)	(0.516)	(2.806)	(0.516)	(2.808)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,109	1,109	1,109	1,109	1,109	1,109	1,109	1,109
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 12. Price Risk Effects with available insurance and with 50% premium discount (Game III), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	0.548**	0.547**			-0.030	0.026		
	(0.239)	(0.241)			(0.762)	(0.768)		
Standard deviation of Price Distribution			0.444**	0.439**	0.466	0.421		
			(0.173)	(0.174)	(0.544)	(0.545)		
Price Distribution 1							0.489	0.480
							(0.374)	(0.380)
Price Distribution 2							0.261	0.302
							(0.338)	(0.336)
Price Distribution 3							0.553	0.576*
							(0.347)	(0.348)
Price Distribution 4							0.912**	0.832**
							(0.384)	(0.390)
Additional random compensation for participation (1-10)	-0.049	-0.114*	-0.050	-0.116**	-0.050	-0.116**	-0.052	-0.117**
	(0.061)	(0.058)	(0.061)	(0.058)	(0.061)	(0.059)	(0.062)	(0.059)
Risk-aversion (CRRA)		0.676**		0.665**		0.665**		0.674**
		(0.264)		(0.264)		(0.267)		(0.272)
Round order number, as played		0.027		0.027		0.027		0.026
		(0.019)		(0.019)		(0.019)		(0.019)
Constant	9.679***	12.222***	9.681***	12.439***	9.682***	12.430***	9.680***	12.239***
	(1.132)	(3.064)	(1.138)	(3.022)	(1.139)	(3.076)	(1.152)	(3.153)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	656	656	656	656	656	656	656	656
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 13. Price Risk Effects with available insurance and with 100% premium discount (Game III)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Dependent variable: Output choice (0-20)			
Uncertain price round (1=Yes)	0.589**	0.572**			0.012	0.007		
	(0.254)	(0.255)			(0.482)	(0.471)		
Standard deviation of Price Distribution			0.473**	0.459**	0.464	0.454		
			(0.197)	(0.197)	(0.383)	(0.376)		
Price Distribution 1							0.252	0.219
							(0.274)	(0.267)
Price Distribution 2							1.004***	1.018***
							(0.328)	(0.334)
Price Distribution 3							0.052	0.030
							(0.410)	(0.408)
Price Distribution 4							1.054***	1.030***
							(0.308)	(0.310)
Additional random compensation for participation (1-10)	-0.019 (0.048)	-0.005 (0.048)	-0.018 (0.048)	-0.004 (0.048)	-0.018 (0.048)	-0.004 (0.048)	-0.021 (0.048)	-0.005 (0.047)
Risk-aversion (CRRA)		0.230		0.237		0.237		0.249
		(0.223)		(0.222)		(0.221)		(0.221)
Round order number, as played		0.014		0.013		0.013		0.012
		(0.015)		(0.015)		(0.015)		(0.015)
Constant	9.575***	12.771***	9.565***	12.600***	9.564***	12.603***	9.566***	12.533***
	(0.433)	(2.566)	(0.434)	(2.551)	(0.434)	(2.554)	(0.424)	(2.533)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151
Number of subjects	101	101	101	101	101	101	101	101

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

Table 14. Price Risk Effects with available insurance and with 100% premium discount (Game III), only Risk-Averse subjects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Output choice (0-20)							
Uncertain price round (1=Yes)	0.880***	0.870***			0.603	0.668		
	(0.314)	(0.317)			(0.683)	(0.655)		
Standard deviation of Price Distribution			0.670***	0.658***	0.226	0.165		
			(0.250)	(0.254)	(0.569)	(0.556)		
Price Distribution 1							0.692**	0.701**
							(0.347)	(0.328)
Price Distribution 2							1.300***	1.308***
							(0.425)	(0.430)
Price Distribution 3							0.119	0.059
							(0.569)	(0.577)
Price Distribution 4							1.404***	1.397***
							(0.400)	(0.408)
Additional random compensation for participation (1-10)	-0.033	-0.073	-0.032	-0.069	-0.033	-0.072	-0.036	-0.075
	(0.061)	(0.067)	(0.061)	(0.067)	(0.062)	(0.067)	(0.063)	(0.066)
Risk-aversion (CRRA)		0.643**		0.644**		0.643**		0.670**
		(0.307)		(0.305)		(0.307)		(0.305)
Round order number, as played		0.031		0.030		0.030		0.030
		(0.023)		(0.024)		(0.023)		(0.023)
Constant	9.246***	10.719***	9.219***	10.405***	9.234***	10.625***	9.267***	10.316***
	(1.017)	(3.132)	(1.017)	(3.073)	(1.016)	(3.119)	(0.983)	(3.035)
Eckel-Grossman lottery played after the 3 games	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Three games order dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	665	665	665	665	665	665	665	665
Number of subjects	60	60	60	60	60	60	60	60

*** p<0.01, ** p<0.05, * p<0.1. Notes: Clustered standard errors at the subject level in parentheses. All regressions include random effects. Other control variables include the same as in Table 3.

6.4. Robustness checks

All results in Tables 3 to 8 are significant when using randomization inference. Using fixed effects instead of random effects, the estimated impacts of price risk on production remain very similar in terms of sign, magnitude. Moreover, restricting the sample to the 93 subjects who chose the optimal production level (10) at least once in certain rounds (who should have understood the game better than the full sample), our estimates remain very similar. Restricting the sample to the 15 first real rounds they played, we also find very similar results.

Restricting the sample to the 62 "more rational" subjects who chose the optimal production level (10) at least once in certain rounds, production levels between 5 and 15 in all certain rounds, and production levels which led to non-negative round profits, our results lose significance but keep their sign, and those that remain significant (specifications 5 and 6) have smaller point estimates; for both the full (62) and risk-averse subsample (40). For game II, the impact of price risk in specifications 5 and 6 for the full sample becomes significant (although this was significant in Table 5 when using randomization inference); all other estimates remain non-significant, for the full sample and the risk-averse subsample. For game III, we find non-statistically significant results for any specifications, and larger standard errors, although the sign of significant coefficients in the main results (tables 7 and 8) remain the same for the restricted sample. This result suggests the "more rational" subjects did not necessarily over produce in the presence of voluntary insurance. However, they over produced the most when motivated to buy insurance through additional premium discounts.

Finally note that our results are robust to the presence of the house-money effect, and not affected by context-specific variables.

6.5. Treatment heterogeneity

In the end of experiment questionnaire, we gathered information about the percentage of potato production usually destined to be consumed by the own household, i.e., percentage of self-consumption. The 58.4% of subjects declared they consume less than 50% of their production, i.e., they are net-sellers of potato. Since theory suggests price risk may affect net-sellers and net-consumers differently (Finkelshtain and Chalfant, 1991, 1997), we replicate the estimations in tables 3, 5 and 7 for the subsample of net-sellers of potato. For this subsample, point estimates are very similar than those for the full sample: non-significant results for the full sample remain non-significant, but some significant results become less significant, although they keep the same sign and similar magnitudes. Note however that potato might not be the only crop or the most important for these farmers, so we cannot generalize these results to all net-sellers of all crops.

In the end of experiment questionnaire, we also asked an open question about what subjects do in real life when the output sale price is low at the time they harvest. Given that potatoes can be stored for a certain amount of time, and the higher altitude allows for non-expensive storage for longer time, some farmers mentioned if the sale price were too low at the time they harvest, they would not sell their production but store it for a few weeks or months instead. Nonetheless, 39.6% of the subjects mentioned they would sell their production at the market price at the time of the harvest, no matter what. We replicate the estimations in tables 3, 5 and 7 for the subsample of subjects who reported they would not use any coping mechanism when prices are low, and they would simply sell at the market price. Our results show that under price risk and no insurance, these subjects underproduce at the extensive margin, i.e., Sandmo's prediction holds. Moreover, for this subsample of farmers we find no significant impacts of price risk on production when insurance (compulsory or non-compulsory) exists. These findings suggest offering insurance is especially important for those without available mechanisms to cope with price risk—in line with Mobarak and Rosenzweig (2013)—who will lose more from price risk (game I), but who would not over produce under either compulsory or non-compulsory insurance (games II and III).

Finally, given that the risk-aversion lottery we use in our experiment, introduced by Eckel and Grossman (2002), originally aimed to compare risk-aversion between men and women—and the authors concluded women are more risk-averse than men—we check whether our results change are different by gender (Hillesland, 2019; Magnan *et al.*, 2020). Likewise, we observe, on average, women in our sample are more risk-averse than men (see Figure 7): the average CRRA was 0.84 for women and 0.68 for men.

We replicate our main results (in tables 3, 5 and 7) for the subsample of women and find the coefficients in game I and game II for women are very similar to the full sample, but some coefficients decrease their significance. Interestingly, the additional compensation and risk-aversion coefficients become significant for the subsample of women. The results differ for game III, where we find no significant impact of price risk on production among female subjects. This suggests that most of the increased production (i.e., moral hazard) when price insurance is available is driven by male subjects, who happen to be less risk averse.

6.6. Limitations

Like any other lab-in-the-field experiment, ours has two main limitations: its results are subject to hypothetical bias and it lacks external validity. Regarding the hypothetical bias, recall that real-world farmers are exposed to more than one type of uncertainty at the same time, they have liquidity constraints, etc. Thus, it is not possible to test production under output price risk only in a real-world setting. The extent of the external validity of our experiment can be in a real-life context or in different settings. Although the literature comparing lab and field outcomes is growing (Berge *et al.*, 2015), we cannot claim external validity of our experiment. Nonetheless, by running part of our experiment (game I) in a similar fashion to Bellemare, Lee and Just's (2020), we provide external validity to the finding that Sandmo's prediction—underproduction in the presence of price risk—does not hold.

There are also some threats to external validity regarding lab and lab-in-the-field-experiments that our experimental design and implementation took care of. First, our experiment is robust to time-preferences, given that rounds were independent of each other. Second, although our subjects were all potato farmers, we did not contextualize the experiment to potato farming to increase internal validity. Moreover, the price insurance in our experiment was not framed as a tool to manage farm risk, nor as a stand-alone investment where a loss can happen (Babcock, 2015). Third, we collected information about context-specific variables (hunger and weather), which could have influenced our results (Kim and Lee 2014; Knetsch and Wong 2009), but we show they do not seem to be affecting our results. We can conclude that our experiment is "narrowly bracketed" (Verschoor, D'Exelle and Perez-Viana, 2016). Finally, given that one of the authors is from the zone where we run the experiment, we discard the presence of the white-man effect in our results.

Another limitation of our study is that we assess insurance demand roughly by using only 0%, 50% or 100% discount on the actuarially-fair premium. This impedes to conclude on the demand for price insurance when offering small discounts on the actuarially-fair premium, or when profitable premiums (for an insurance firm) are offered.

7. Conclusion

Farmers must inevitably face risks. Revenue comes from volatile production and volatile prices, but insurance schemes in developing countries have focused on covering production risks. Using a lab-in-the-field experiment, with 101 Peruvian potato farmers, our study is the first assessing whether price risk changed production levels when there is no price insurance, when insurance is compulsory, and when it is voluntary—subsidized or unsubsidized.

Our results show the presence of price risk does not lead to underproduction, like Bellemare, Lee and Just (2020), i.e., Sandmo's EUT prediction does not hold. Nonetheless, other measures of price risk suggest underproduction might exist. When compulsory price insurance in introduced, we find no significant differences in production with or without price risk. This suggests compulsory insurance fixes the market failure—as EUT predicts—and brings production back to certain price levels.

By offering voluntary price insurance we find a large demand for it (70.8% without subsidies), which increases with more premium discounts. This take-up is even larger than the most successful pooled indexed microinsurance schemes have reached. This suggests that basing insurance schemes in more familiar measures (like output prices), covering more frequent events (than catastrophic insurance) can be a more effective form to insure farmers. Regarding production, under price risk and voluntary price insurance (and available premium discounts), we find production is larger than under price certainty, even more when offering 100% premium discounts; suggesting the presence of moral hazard. Our results contrast with Zhang and Palma's (2020), who find that both compulsory and voluntary insurance bring moral hazard.[24] Altogether, these results suggest implementing compulsory price insurance schemes, at an unsubsidized actuarially-fair premium, would allow to protect farmers against price risk and to avoid moral hazard.

Finally, note that our study measures the changes in production in the short run, but different impacts can be observed in the long run, for instance, farmers facing continuous price risk would permanently change crops or stop changes towards changing crops. (Cole, Giné and Vickery, 2017).

---

[24] Note Zhang and Palma (2020) also analyze adverse selection, but our design does not allow adverse selection. Defining adverse selection as the fact that high risk agents are ready to pay more than lower risk agents for additional coverage (Rothschild and Stiglitz, 1976; Chiappori et al., 2006), given that in our design subjects always must fully insure their production (in games II and III), it does not allow adverse selection.

The actual implementation of price insurance is out of the scope of our paper. Nonetheless, we recognize a mandatory price insurance scheme should be implemented carefully to address all farmers' needs (Platteau, De Bock and Gelade, 2017), and to avoid middle men to collude to put in place a low price.

References

Babcock, B. A. (2015) 'Using Cumulative Prospect Theory to Explain Anomalous Crop Insurance Coverage Choice', *American Journal of Agricultural Economics*, 97(5), pp. 1371–1384. doi: 10.1093/ajae/aav032.

Baron, D. P. (1970) 'Price Uncertainty, Utility, and Industry Equilibrium in Pure Competition', *International Economic Review*, 11(3), pp. 463–480.

Batra, R. N. and Ullah, A. (1974) 'Competitive Firm and the Theory of Input Demand under Price Uncertainty', *Journal of Political Economy*, 82(3), pp. 537–548.

Bellemare, M. F., Lee, Y. N. and Just, D. R. (2020) 'Producer Attitudes Toward Output Price Risk: Experimental Evidence from the Lab and from the Field', *American Journal of Agricultural Economics*, 102(3), pp. 806–825. doi: 10.1002/ajae.12004.

Berge, L. I. O. *et al.* (2015) 'Competitive in the lab, successful in the field?', *Journal of Economic Behavior and Organization*. Elsevier B.V., 118, pp. 303–317. doi: 10.1016/j.jebo.2014.11.014.

Boyd, C. M. and Bellemare, M. F. (2020) 'The Microeconomics of Agricultural Price Risk', *Annual Review of Resource Economics*, (Forthcoming).

Cai, J. (2016) 'The Impact of Insurance Provision on Household Production and Financial Decisions', *American Economic Journal: Economic Policy*, 8(2), pp. 44–88. doi: 10.1257/pol.20130371.

Carter, M. *et al.* (2017) 'Index Insurance for Developing Country Agriculture: A Reassessment', *Annual Review of Resource Economics*, 9(1), pp. 421–438. doi: 10.1146/annurev-resource-100516-053352.

Charness, G., Gneezy, U. and Imas, A. (2013) 'Experimental methods: Eliciting risk preferences', *Journal of Economic Behavior and Organization*. Elsevier B.V., 87, pp. 43–51. doi: 10.1016/j.jebo.2012.12.023.

Cole, S. *et al.* (2013) 'Barriers to Household Risk Management: Evidence from India', *American Economic Journal: Applied Economics*, 5(1), pp. 104–135.

Cole, S., Giné, X. and Vickery, J. (2017) 'How does risk management influence production decisions? Evidence from a field experiment', *Review of Financial Studies*, 30(6), pp. 1935–1970. doi: 10.1093/rfs/hhw080.

Crosetto, P. and Filippin, A. (2016) 'A theoretical and experimental appraisal of four risk elicitation methods', *Experimental Economics*. Springer US, 19(3), pp. 613–641. doi: 10.1007/s10683-015-9457-9.

Duflo, E., Glennerster, R. and Kremer, M. (2007) 'Chapter 61 Using Randomization in Development

Economics Research: A Toolkit', *Handbook of Development Economics*. doi: 10.1016/S1573-4471(07)04061-2.

Eckel, C. C. and Grossman, P. J. (2002) 'Sex differences and statistical stereotyping in attitudes toward financial risk', *Evolution and Human Behavior*, 23, pp. 281–295.

Eckel, C. C. and Grossman, P. J. (2008) 'Forecasting risk attitudes: An experimental study using actual and forecast gamble choices', *Journal of Economic Behavior and Organization*, 68(1), pp. 1–17. doi: 10.1016/j.jebo.2008.04.006.

Elabed, G. and Carter, M. R. (2015) 'Compound-risk aversion, ambiguity and the willingness to pay for microinsurance', *Journal of Economic Behavior and Organization*. Elsevier B.V., 118, pp. 150–166. doi: 10.1016/j.jebo.2015.03.002.

Finkelshtain, I. and Chalfant, J. A. (1991) 'Marketed Surplus under Risk: Do Peasants Agree with Sandmo?', *American Journal of Agricultural Economics*, 73(3), pp. 557–567. doi: 10.2307/1242809.

Finkelshtain, I. and Chalfant, J. A. (1997) 'Commodity Price Stabilization in a Peasant Economy', *American Journal of Agricultural Economics*, 79(4), pp. 1208–1217. doi: 10.2307/1244278.

Harrison, G. W., Lau, M. I. and Elisabet Rutström, E. (2009) 'Risk attitudes, randomization to treatment, and self-selection into experiments', *Journal of Economic Behavior and Organization*, 70(3), pp. 498–507. doi: 10.1016/j.jebo.2008.02.011.

He, J. *et al.* (2020) 'Input use under cost-of-production crop insurance: Theory and evidence', *Agricultural Economics (United Kingdom)*, 51(3), pp. 343–357. doi: 10.1111/agec.12558.

Hill, R. V. (2010) 'Liberalisation and Poducer Price Risk: Examining Subjective Expectations in the Ugandan Coffee Market', *Journal of African Economies*, 19(4), pp. 433–458. doi: 10.1093/jae/ejq010.

Hill, R. V. *et al.* (2019) 'Ex ante and ex post effects of hybrid index insurance in Bangladesh', *Journal of Development Economics*. Elsevier B.V., 136, pp. 1–17. doi: 10.1016/j.jdeveco.2018.09.003.

Hill, R. V. and Viceisza, A. (2012) 'A field experiment on the impact of weather shocks and insurance on risky investment', *Experimental Economics*, 15(2), pp. 341–371. doi: 10.1007/s10683-011-9303-7.

Hillesland, M. (2019) 'Gender differences in risk behavior: An analysis of asset allocation decisions in Ghana', *World Development*. Elsevier Ltd, 117, pp. 127–137. doi: 10.1016/j.worlddev.2019.01.001.

Karlan, D. *et al.* (2014) 'Agricultural Decisions after Relaxing Credit and Risk Constraints', *The Quarterly Journal of Economics*, 129(2), pp. 597–652. doi: 10.1093/qje/qju002.Advance.

Kim, Y.-I. and Lee, J. (2014) 'The long-run impact of a traumatic experience on risk aversion', *Journal of Economic Behavior and Organization*. Elsevier B.V., 108, pp. 174–186. doi: 10.1016/j.jebo.2014.09.009.

Knetsch, J. L. and Wong, W.-K. (2009) 'The endowment effect and the reference state: Evidence and manipulations', *Journal of Economic Behavior and Organization*, 71, pp. 407–413. doi: 10.1016/j.jebo.2009.04.015.

Kouame, E. B. H. and Komenan, A. N. (2012) *Risk Preferences and Demand for Insurance under Price Uncertainty: An Experimental Approach for Cocoa Farmers in Côte D'Ivoire*. 13.

Magnan, N. *et al.* (2020) 'Husbands' and wives' risk preferences and improved maize adoption in Tanzania', *Agricultural Economics (United Kingdom)*, 51(5), pp. 743–758. doi: 10.1111/agec.12589.

Matul, M. *et al.* (2013) *Why People Do Not Buy Microinsurance and What Can We Do About It*. 20.

Mobarak, A. M. and Rosenzweig, M. R. (2013) 'Informal Risk Sharing, Index Insurance, and Risk Taking in Developing Countries', *American Economic Review*, 103(3), pp. 375–380. doi: 10.1257/aer.103.3.375.

Moschini, G. and Hennessy, D. A. (2001) 'Uncertainty, risk aversion, and risk management for agricultural producers', *Handbook of Agricultural Economics*, 1(Chapter 2), pp. 87–153.

Mullally, C., Boucher, S. and Carter, M. (2010) 'Perceptions and Participation: Mistaken Beliefs, Encouragement Designs, and Demand for Index Insurance', in *Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA*.

Platteau, J. P., De Bock, O. and Gelade, W. (2017) 'The Demand for Microinsurance: A Literature Review', *World Development*. Elsevier Ltd, 94, pp. 139–156. doi: 10.1016/j.worlddev.2017.01.010.

Ranganathan, T., Gaurav, S. and Singh, A. (2016) 'Demand for Price Insurance among Farmers in India : A Choice Experiment-based Approach', *Margin - The Journal of Applied Economic Research*, 10(2), pp. 198–224. doi: 10.1177/0973801015625266.

Roberts, R. A. J. (2005) 'Insurance of crops in developing countries', *FAO Agricultural Services Bulletin 159*, p. 78. Available at: http://books.google.com/books?hl=en&lr=&id=LEB5yhuD7SsC&oi=fnd&pg=PR7&dq=Insurance+of+crops+in+developing+countries&ots=X8NwCPBT7Z&sig=KDUYh9FNvDgSJ6DtBres7sah0Co.

Sandmo, A. (1971) 'On the Theory of the Competitive Firm Under Price Uncertainty', *American Economic Review*, 61(1), pp. 65–73.

Sarris, A. (2002) *The Demand for Commodity Insurance by Developing Country Agricultural Producers. Theory and an Application to Cocoa in Ghana*, *Policy Research Working Paper Series*. Available at: http://econ.worldbank.org/view.php?type=5&id=18744.

Thaler, R. (1985) 'Mental Accounting and Consumer Choice', *Marketing Science*, 4(3).

Verschoor, A., D'Exelle, B. and Perez-Viana, B. (2016) 'Lab and life: Does risky choice behaviour observed in experiments reflect that in the real world?', *Journal of Economic Behavior and Organization*. Elsevier B.V., 128, pp. 134–148. doi: 10.1016/j.jebo.2016.05.009.

Wong, H. L. *et al.* (2020) 'Effects of input vouchers and rainfall insurance on agricultural production and household welfare: Experimental evidence from northern Ethiopia', *World Development*. Elsevier Ltd, 135, p. 105074. doi: 10.1016/j.worlddev.2020.105074.

Zhang, P. and Palma, M. A. (2020) 'Compulsory Versus Voluntary Insurance: An Online Experiment', *American Journal of Agricultural Economics*, 00(00), pp. 1–20. doi: 10.1111/ajae.12120.

Appendix

A.1. Figures

Figure 1. Output choice distribution in Game I (price risk without insurance)

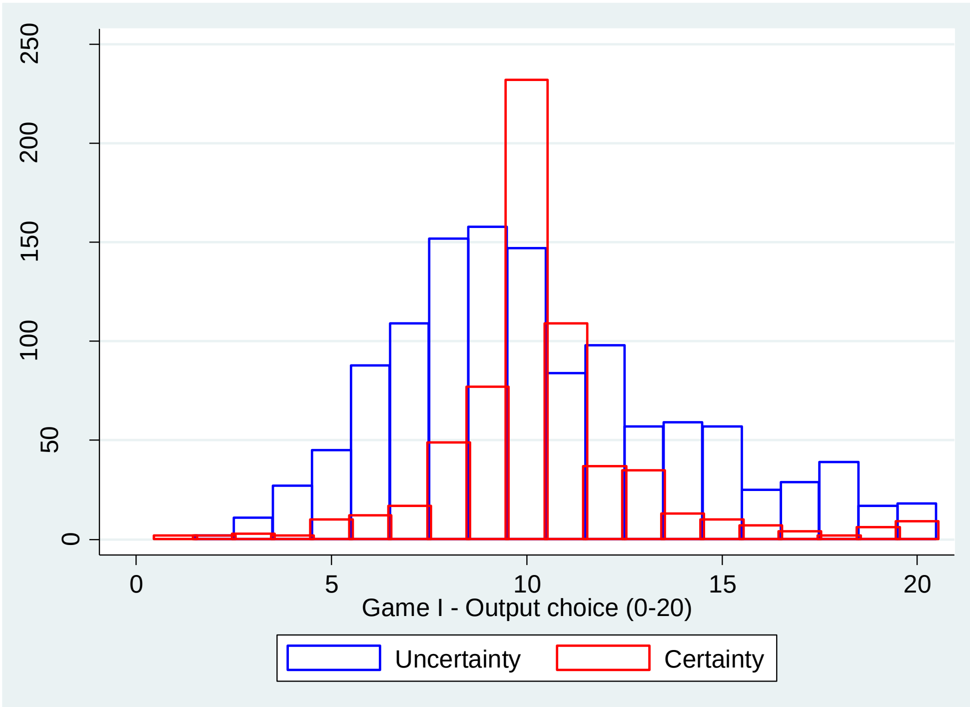

Figure 2. Output choice distribution in Game II (price risk and compulsory insurance)

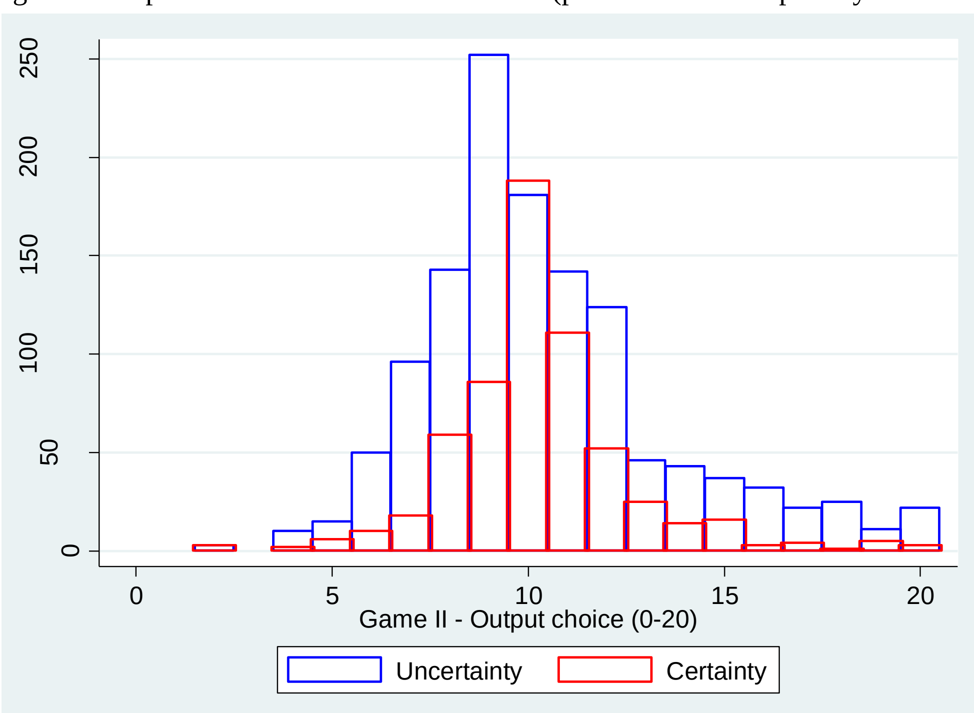

Figure 3. Output choice distribution in Game III (price risk and available insurance) with 0% discount

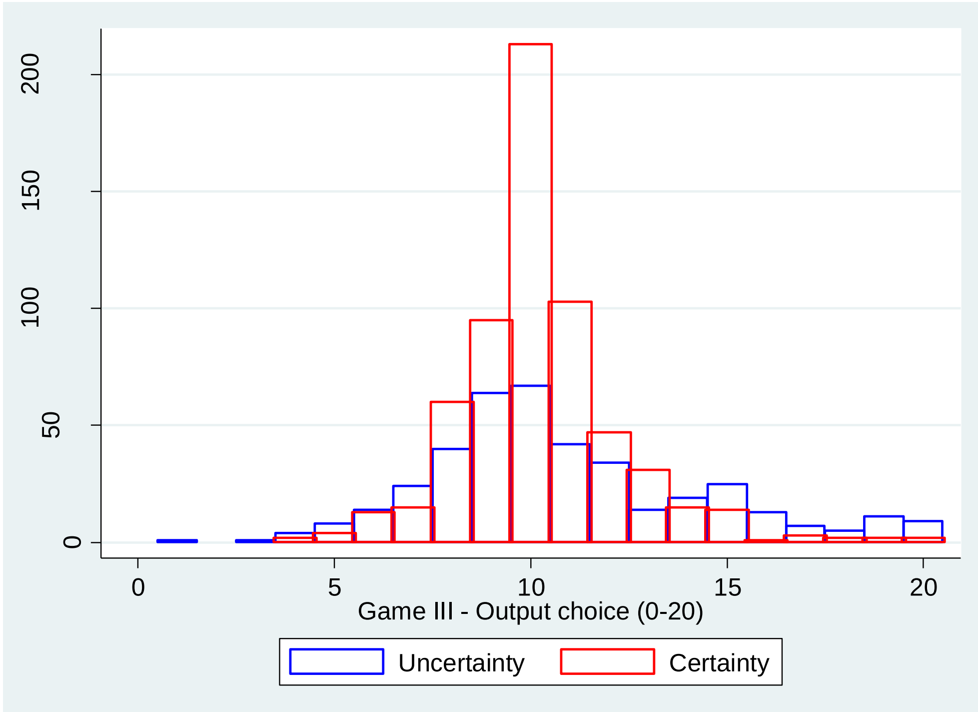

Figure 4. Output choice distribution in Game III (price risk and available insurance) with 50% discount

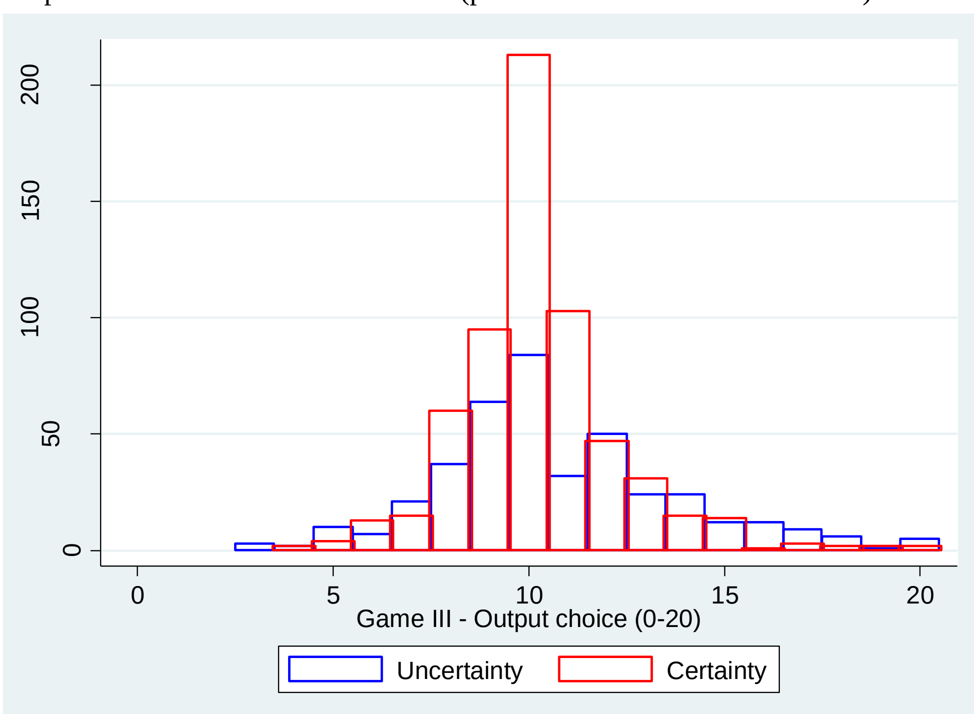

Figure 5. Output choice distribution in Game III (price risk and available insurance) with 100% discount

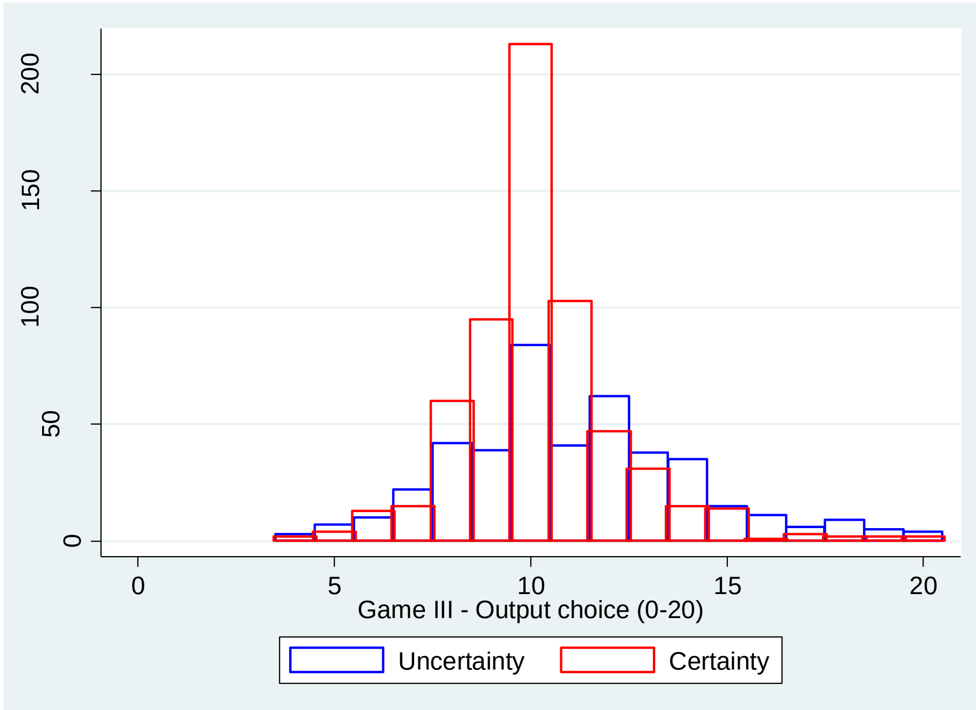

Figure 6. Output choice distribution in Game III (price risk and available insurance), for those who purchased the insurance

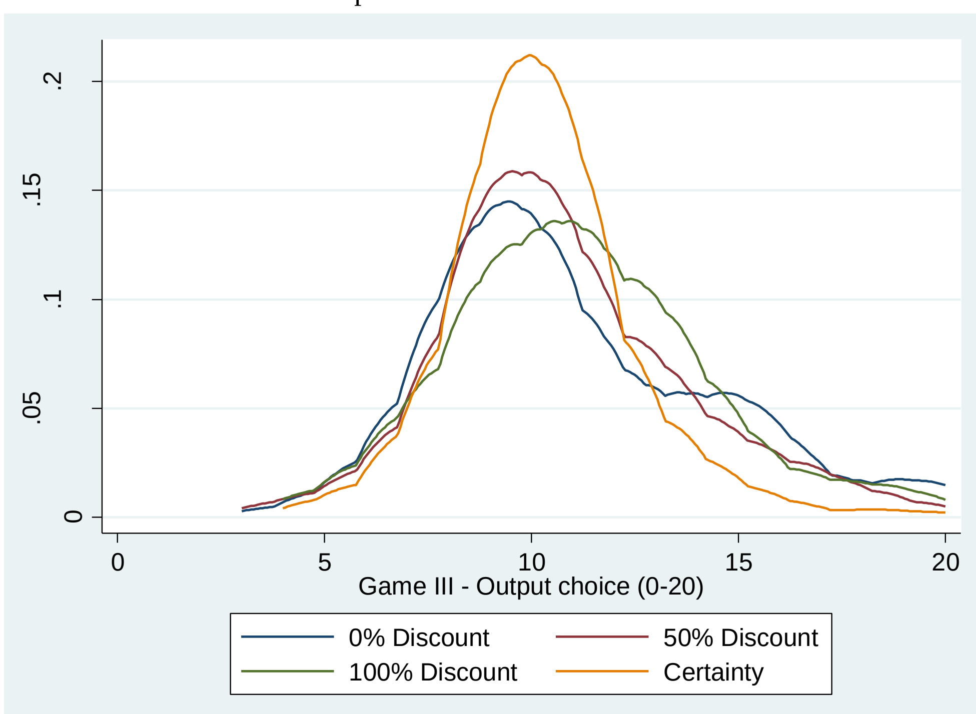

Figure 7. Risk Aversion by Gender