Production Decision Making under Price Ambiguity:

An Experimental Evidence

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Selected Paper prepared for presentation at the 2018 Agricultural & Applied Economics Association Annual Meeting, Washington, D.C., August 5-August 7

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May 10, 2018

Abstract

Previous researchers including Sandmo (1971) explored theories of production under price uncertainty. These theories were developed under the framework of expected utility, in which producers are assumed to know probability distributions of prices. Very little is known, however, about how production decisions are made when probability distributions of prices are unknown, i.e., when individuals are facing price ambiguity. We generate unique experimental data to examine how individuals make production decisions when they are informed only of the possible range of prices in a series of rounds. To do that, we conduct lab experiments with undergraduate students in the U.S. and farmers in rural Peru. We find that price ambiguity causes subjects to increase production, but the results are sensitive to prices drawn during experimental sessions as well as subjects' risk attitudes. We also find that subjects incorporate past price information when making production decisions, and current price information matters more than older information. Lastly, we find some patterns of decision making consistent with gambler's fallacy and prospect theory. All in all, we find that, when producers have to make production decisions lacking information on price distributions, contexts matter a great deal, and individuals rely on past realization of prices as well as heuristics to facilitate decision making.

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1 Introduction

How do producers make production decisions under output price ambiguity? Previous researchers (Sandmo, 1971; Batra and Ullah, 1974) developed theories of production under price uncertainty. Sandmo's theory famously predicted that, under price uncertainty, a risk-averse producer produces at a level lower than the optimal level of production under price certainty, failing to maximize profits (Sandmo, 1971). Batra and Ullah (1974) predicted that a producer who exhibits DARA (decreasing absolute risk aversion) would monotonically decrease the level of production according to a mean preserving spread of an output price distribution. These theories were developed under an assumption that producers know the distribution of output prices. We lack both theoretical and empirical evidence, however, on how production decisions are made when probability distributions of prices are unknown. Hereafter, we call price uncertainty with an unknown probability distribution *price ambiguity*, and distinguish this concept from *price risk*−price uncertainty with a known probability distribution.[1] Understanding how production decisions are made under price ambiguity is very relevant to the context of agriculture in developing economies in which farmers often face challenges in accessing market information due to various middlemen that create barriers for information flows (Sodhi and Tang 2014), incomplete insurance and credit markets, and significant information asymmetry between market participants (Chen and Tang, 2015).

In this paper, we first examine how production decisions are made under output price ambiguity. Do producers increase or decrease production levels under price ambiguity compared to the situation of price certainty? How do producers incorporate price information when making production decisions? Secondly, given that individuals are provided with only a limited amount of information on prices, we are interested in figuring out whether any behavioral anomalies are observed in decision making. Specifically, we examine whether producers show patterns of behavior consistent with gambler's fallacy (Tversky and Kahneman, 1971), framing (Meredith and Salant, 2011), prospect theory (Kahneman and Tversky, 1979), and safety-first decision making (Telser 1995; Bigman 1996). Lastly, we investigate if there are any systematic differences in decision making patterns across contexts. Thus, we generate unique experimental data based on a simple decision-making game designed to study how producers make production decisions facing output price ambiguity, i.e., knowing only the range, not distribution, of possible prices.

Empirical studies on decision making under price ambiguity have focused on the formation of reference prices of financial commodities (Arkes et al., 2008; Baucells et al, 2011; Chen and Rao, 2002) and how reference prices affect investment and selling decisions in financial markets (Gneezy, 2005; Lee et al., 2008). Another strand of empirical literature on decision making under price ambiguity investigates producers' marketing decisions under price uncertainty. A recent study by Mattos and Zinn (2016) conducted a set of experiments on price information and marketing

[1] Uncertainty of unmeasurable nature is called Knightian risk following the name of economist Frank Knight (1885-1972) who distinguished measurable uncertainty and unmeasurable uncertainty in his work (Knight, 1921).

decisions with Canadian grain producers and find that producers form reference prices based on the current market price, the highest price to date, and the expected price (Mattos and Zinn, 2016). Another paper related to our study is an experimental work by Warnick et al. (2011). They conducted experiments to measure farmers' risk and ambiguity aversion in rural Peru to examine their relationships with crop diversification. They find that farmers' ambiguity aversion is negatively associated with crop diversification, while risk aversion has no measurable association with crop diversification (Warnick et al., 2011).

This study contributes to the literature in the following ways: First, to the best of our knowledge, this is the first study to examine production decision making under output price ambiguity. Previous studies focused on farmers' marketing decisions (Mattos and Zinn, 2016) or crop diversification (Warnick et al., 2011), but not production. From a policy perspective, understanding the effect of price ambiguity on production can inform policies to alleviate food insecurity in developing countries. For example, if price ambiguity contributes to decreases in production, efforts to provide a better access to price information on agricultural commodities to farmers might be helpful in increasing production. In conjunction with findings in Bellemare et al. (2017) in which producer decision making under price risk is examined, this paper contributes to a broader literature on producer decision making under uncertainty. Second, unique data set is generated based on unique lab experiments designed specifically to examine how producers make production decision under price ambiguity. Given the charts that show relationships between production decision, costs, and profits under different price scenarios, subjects are asked to make production decisions in subsequent rounds.[2] For internal validity, in every round, we randomize between situations of output price certainty and price ambiguity. With our experimental subjects, we also elicit risk attitudes using the list design by Holt and Laury (2002). For external validity, we conduct our experiments in the lab with student subjects in the U.S., and we take our lab experiments to the field and conduct the same experiments with minimal necessary adjustments with farmers in rural Peru.

The paper proceeds as follows: Section 2 and 3 describe the experimental design and the data, respectively. Sections 4 discusses the empirical strategy, and section 5 presents the results, robustness checks, and limitations. The paper is summarized and future directions are discussed in Section 6.

2 Experimental Design

In every session, each subject played two types of experiments−price ambiguity experiment and Holt-Laury list experiment. After finishing both experiments, subjects were asked to fill out basic

[2]Cost and profit functions used in this experiment are convex and concave in the level of output, respectively, and follow the functional forms used in Sandmo's (1971) theoretical model of production decision making under output price uncertainty.

demographic information. Then, each participant received cash payoffs at the end of the session. Subjects spent about 90 to 120 minutes for the experiments and remuneration. Four sessions are conducted in total. First three sessions were conducted in the U.S. with undergraduate students, and the last session was conducted in Peru with smallholder farmers.

2.1 Price Ambiguity Experiment

In the price ambiguity experiment, each subject hypothetically played a role of a wheat producer and was asked to decide how many units of wheat to under price certainty or price ambiguity. There were five possibilities for the selling price of wheat−$\$5, \$6, \$7, \$8$, and $\$9$ per bushel. Subjects could choose any integer from 0 to 20 as levels of production x (in 1,000 bushels). A simple cost function convex in x with a fixed cost of 15 (in $\$1,000$), $c(x) = 2x^{1.4} + 15$, was used. Accordingly, a simple profit function $\pi = p \cdot x - c(x) = p \cdot x - 2x^{1.4} - 15$ that is concave in x was used. Each subject was given charts that describe, the amount of costs to be incurred according to production levels 0 through 20 (in 1,000 bushels), and corresponding profits (in $\$1,000$). Each subject was also given a summary chart that shows only the relationship between the production level and the profit under the five price scenarios. See Appendix I for the charts.

The structure of the game is described in figure 1. In each round, subjects were randomly given one of the two situations: (1) Selling price of wheat will be exactly $\$7$ (price certainty); (2) Selling price of wheat will be one of the five values−$\$5, \$6, \$7, \$8$, or $\$9$ per bushel (price ambiguity). Under each given situation, subjects were asked to determine how much wheat to produce by choosing any integer between 0 and 20 as their production level. After every subject has made her own production decision, a real ping pong ball was randomly drawn from a bag containing 80 balls described in figure 2. The bag was shown to the subjects, but the distribution was not shown. In each round, randomization was conducted to determine the situations of price certainty and price ambiguity. In the lab, experimenters drew a random integer between 1 and 3. Number 1 (2 or 3) corresponded to the situation of price certainty (ambiguity). This randomization procedure was made public to all participants in each session using an excel spreadsheet and a beam projector in the lab. Therefore, this experimental design allows within-subject variation in prices over rounds, but no between-subjects variation in prices in each given round.

Ten practice rounds were played in the beginning to help subjects understand the experiment. Subjects were allowed to freely ask questions to facilitate their decisions during the practice rounds. Ample time was given between rounds to make sure that subjects understand the relationship between the decisions and the profits that they made. Then, twenty real rounds were played in which remunerations were directly related to the profits subjects make. Subjects were allowed to look at the charts and take notes throughout the session.

2.2 Holt-Laury List Experiment

The list experiment developed by Holt and Laury (2002) was conducted to elicit subjects' attitudes to income risk. Each subject was presented a table of ten paired lotteries, A and B, from which she was asked to choose one that she preferred. Lottery B is always riskier than lottery A. In the first row, expected value of lottery A is greater than that of B, and as row number proceeds, the difference in the expected values decreases. Eventually, the expected value of B exceeds that of A. If a subject chooses option A, then she proceeds to the next row. If she chooses option B, she was asked to stop. Thus, we enforced monotonic switching. For example, if a subject switched from option A to B in row 5, it was assumed that she would have chosen option B from row 5 and on. A higher row number in which a subject switched from lottery A to lottery B corresponds to a greater degree of income risk aversion.

2.3 Payoff Scheme

In the price ambiguity experiment, each subject started from an endowment of \$25. In a given round, profit ranges between $-\$47.58$ and \$32.61. At the end of the session, for each subject, one round was randomly selected among the 20 actual rounds by making the subject roll a 20-sided die. The payoff from the price ambiguity experiment was determined by summing up the \$25 endowment and a half of the profit in the randomly selected round. For example, if a subject made a loss of 30 in the selected round, her final payoff was determined as $\$25 + (-\$30 \times 0.5) = \$10$. The final payoff from the price ambiguity game ranged between \$1.21 and \$41.31.

The payoff from the Holt-Laury list experiment was determined in the following way: A random number between 1 to 10 was drawn by each subject using a ten-sided die to determine a row number. Then, according to the choice of A or B made by the subject and the probabilities given in lotteries A and B, payoff was determined by rolling a ten-sided die again. For example, suppose that the first random number drawn was 7 and also that the subject switched from lottery A to B in the fifth row. Then, according to the choice made by the subject, lottery B in the row 7 is played by rolling a ten-sided die. If the number drawn from the second roll of a die was 7 or less, then the subject receives \$3.85. If the number was 8 or higher, then the subject receives \$0.1. The payoff from the Holt-Laury List Experiment ranged between \$0.1 and \$3.85.

Subjects received \$45 for compensation for their time and for filling out demographic information, and in addition earned a sum of payoffs between \$1.31 and \$45.16 from the price ambiguity and Holt-Laury experiments depending on their performance and luck. Experimenters explained the payment scheme in the beginning of each experiment, but actual cash payments were made after all the experiments were finished.

2.4 Experiments with Peruvian Farmers

For experiments in rural Peru with smallholder farmers, the experimental protocol was translated from English to Spanish, making only minimal necessary changes. The crop was changed from wheat to potato, the crop produced more commonly in Peru. Numbers for the range of production levels (0-20), range of prices (5-9), and cost and profit functions remained unchanged and only units were changed, making sure that the numbers are reasonable in the context of recent prices. For example, the unit of production was changed from 1,000 bushels to 10 kilos; the unit of prices was changed from USD (\$) per bushel to Nuevos Soles (PEN, or $S/.$) per 10 kilos. To facilitate understanding of randomization during the price ambiguity experiment, enumerators carried a panel of randomization chart (See Appendix IV) and showed it to subjects. For Holt-Laury list experiment, both pictures (See Appendix V) and the original list were presented to subjects to facilitate understanding. Proportion of the participation fee and endowments for the price ambiguity game remained unchanged.[3]

3 Data and Summary Statistics

Experiments were conducted in three locations over four sessions. Sessions 1 and 2 were conducted in December 2014 and March 2015, respectively, in the Lab for Experimental Economics and Decision Research (LEEDR) at the Dyson School of Applied Economics and Management at Cornell University. Cornell's LEEDER lab has a rule that does not allow deceiving subjects. For each session, 24 subjects were recruited via LEEDR lab's listserv, and the subjects were undergraduate students enrolled in the Dyson School. Session 3 was conducted at the University of Minnesota in October 2015. Subjects were recruited via undergraduate listserv of the Department of Applied Economics at the University of Minnesota. 24 subjects were recruited, but only 19 showed up due to weather. Session 4 was conducted in rural Peru in collaboration with the Innovations for Poverty Action (IPA) in Lima, Peru in August and September 2016. Farmers were contacted and recruited by two enumerators in the rural vicinity of Lima, and efforts were made to make sure that farmers are literate and numerate. Several screening questions were asked to make sure that they understand basic concepts of probability, and 48 farmers participated in experiments. Therefore, throughout all sessions, 115 subjects participated.

There are several notable differences across sessions and locations. First, for sessions 1, 2, and 3 conducted in the U.S., experiments were conducted in a group setting in the lab (Cornell) or in a classroom (Minnesota) by authors. On the other hand, for session 4 conducted in rural Peru, two enumerators who speak Spanish conducted experiments one-on-one with each participant.

[3] For experiments in the U.S., the participation fee and the endowments (from which a subject can lose almost all or can gain more depending on the results of the price ambiguity experiment) were 45 USD and 25 USD, respectively. For experiments in Peru, these amounts were 45 PEN and 25 PEN, respectively.

Therefore, in sessions 1, 2, and 3, there is only within-subject variations in the prices drawn in each round and no between-subjects variations. In session 4, however, there are both between-subjects and within-subject variations in prices. Secondly, we were interested in figuring out whether the order of the games conducted affects production choices. Thus, in session 1, we conducted the price ambiguity game first, and the Holt-Laury list experiment was conducted later. In sessions 2 and 3, the Holt-Laury list experiment was conducted first. In session 4 in which experiments were conducted one-on-one with subjects, the order was randomized for each subject using a throw of die. Table 1 summarizes the date, location, number of subjects, and order of games of each session.

Table 2 presents summary statistics for the pooled sample from all sessions. Because there are a total of 115 subjects and each subject plays 10 practice and 20 actual rounds of the price ambiguity game, there are $115 \times 30 = 3,450$ subject-round observations. Mean value of production level was about 10.76 units, and the situation of price uncertainty was drawn 68% of all rounds. On average, during the Holt-Laury list experiments, subjects switched from option A (safe option) to option B (risky option) between rows 5 and 6, indicating that an average subject is slightly risk-averse. Figure 3 is a histogram of production levels chosen in the real rounds (11-30) under the situation of uncertainty.

Tables 3, 4, 5, and 6 present summary statistics for the sub-samples corresponding to the sessions 1, 2, 3, and 4, respectively. The average Peruvian farmer is significantly older than the average student in the U.S. Another noticeable difference between the student subjects in the U.S. and farmer subjects in Peru is their risk attitudes. During the Holt-Laury list experiment, subjects who participated in sessions 1 through 3 on average switched from the option A to option B either in row 6 or 7, indicating risk aversion. On the other hand, Peruvian farmers switched either in row 3 or 4 on average, indicating risk loving or risk neutrality.

Figure 4 shows histograms of the prices drawn during the practice rounds (rounds 1-10) in each session. Interestingly, in session 1, only prices of 5 and 7 were randomly drawn during the practice rounds. On the other hand, in session 2, only high prices (7, 8, and 9) were randomly drawn. Given the concern that the price drawn during the practice rounds may significantly affect priors for the prices during the real rounds, in session 3, authors intentionally drew prices from a uniform distribution without replacements. In session 4, prices were drawn randomly for each subjects in each round, and the histogram looks like a normal distribution.

Figure 5 shows histograms of the production levels chosen under uncertainty in real rounds (rounds 11-30) in each session. From inspection, it is noteworthy that the levels of production chosen in session 2 tend to be higher than those in session 1. In session 3 in which prices were drawn from a uniform distribution without replacements, in surprisingly many times (about 60% of all subject-round observations), subjects chose to produce at 10, the optimal level of production when price is 7. In session 4, we see greater variations in the production levels.

4 Empirical Strategy

For empirical analysis, we estimate the following panel regression:

$$Y_{i,t} = \beta_0 + \beta_1 U_{i,t} + \beta_2 \overline{P}_{i,t-1} + \beta_3 \overline{V}_{i,t-1} + \beta_4 Z_i + C_i + t + \epsilon_{i,t} \quad (1)$$

$Y_{i,t}$ is subject i's choice of production level in round t. $U_{i,t}$ is 1 if price is uncertain in round t and 0 otherwise. $\overline{P}_{i,t-1}$ is a cumulative average of prices from round 1 to round $t-1$ for subject i, and $\overline{V}_{i,t-1}$ is a variance of prices drawn drawn from round 1 to round $t-1$ for subject i. Z_i is a vector of observed individual-specific characteristics, such as the row number of switch in the Holt-Laury game that indicates risk attitudes, gender, and age, and C_i is an effect specific to individual i. t is a linear time trend for round. Lastly, ϵ_{it} is an error term with an expected value of zero, with standard errors clustered in subject level.

We estimate an OLS with random effects model, because our experimentally-assigned variables of interest (namely, $U_{i,t}$, $P_{i,t-1}$, and $V_{i,t-1}$) are orthogonal to the error term. Hausman specification test indicates that random effects and fixed effects models are not significantly different. Given that random effects models are more efficient than fixed effects models, we estimate random effects model.

5 Results

5.1 Main Results

Table 7 shows the main results. Throughout columns (1)-(5), we can see that individuals increased their production level by about half unit on average when faced with price ambiguity as opposed to price certainty, and that the coefficient is statistically significant. Columns (2)-(5) show that a dollar (or a Peruvian Sole) increase in the cumulative average of the prices drawn up to a previous round significantly increases production level by 1.2-1.7 units. Cumulative variance of the prices drawn up to a previous round does not have a significant impact on production, implying that levels of past prices may matter more than the volatility of prices. Individual's switch point during the Holt-Laury game has a negative and significant coefficient estimate, indicating that a greater degree of income risk aversion is significantly associated with lower levels of production. We can also observe that, as rounds proceed, individuals tend to choose higher levels of production. Being a female does not have a significant effect on the choices of production level.

Table 8 presents how individuals incorporate price information from various windows of time horizon in making production decisions, displaying the coefficient estimates on the cumulative average price from all previous rounds (column (1)), 4-periods (column (2)), 3-periods (column (3)), and 2-periods moving average prices (column (4)), and one-period lagged prices (column (5)). Going

from the results in columns (1) to (4), we can see that the magnitude of the coefficient estimates monotonically decreases, indicating that individuals tend to use full information when making the production decisions. However, from column (5), we can see that the magnitude of the coefficient estimate on one-period lagged prices is greater than the those of the moving averages, suggesting that the most current price information matters more than older information. This is consistent with 'recency effects' in which last event in a series has a disproportionate impact on overall effect (Chen and Rao, 2002) and also with findings from the study by Mattos and Zinn (2016) on producers' reference prices.

5.2 Behavioral Anomalies

In this subsection, we investigate if we can find some evidence of behavioral anomalies or uses of heuristics when subjects are faced with price ambiguity.

5.2.1 Gambler's Fallacy

People's tendency to view small sample as representative has been called the law of small numbers (Tversky and Kahneman, 1971), and gambler's fallacy is a famous example. The gambler's fallacy is the mistaken expectation that "any deviation in one direction will soon be canceled by a corresponding deviation in the other (Tversky and Kahneman, 1971)," or, one's belief that sampling is a "self-correcting process (Tversky and Kahneman, 1971)." In other words, it describes a tendency to think that "early draws of one signal increase the odds of next drawing other signals (Rabin, 2002)"

The variable 'underestimation' is the difference between the actual price drawn in the previous round and the expected price in the previous round estimated from the choice of production level. This difference is positive (or negative) when the actual price drawn was greater (less) than the expected price, i.e., when the subject underestimated (or overestimated) the price in the previous round. Coefficient estimates on 'underestimation' in tables 7 and 8 show that underestimating the price in the previous round significantly decreases the level of production in the current round. In other words, having seen a greater-than-expected price being drawn in the previous round, a subject decreases her production level, expecting to see a lower price in the current round. Therefore, our subjects display behavior consistent with gambler's fallacy.

5.2.2 Order Effect

Literature in behavioral economics demonstrate that the order in which options are presented affects choices of individuals. For example, the order in which candidates are listed on a ballot can affect the result of an election (Meredith and Salant, 2011). In the context of our experimental setting, for example, a subject who completed the Holt-Laury list experiment before the price ambiguity

experiment may feel that she has earned some money to gamble on the price ambiguity experiment and thus make riskier choices, if the order effect was present.[4]

To test whether the order of the experiments affects production decisions, we mixed up the order of the price ambiguity experiment and the Holt-Laury list experiment. In session 1, price ambiguity experiment was conducted first; In sessions 2 and 3, the Holt-Laury list experiment was conducted first; In session 4, the order was randomized for each subjects. Enumerators rolled a six-sided die in the beginning of each session to determine which of the two games the subject would play first. If the number was either 1, 2, or 3, the price ambiguity experiment was conducted first; If the number was 4, 5, or 6, then the Holt-Laury list experiment was conducted first.

The variable 'Holt-Laury First' is an indicator variable equal to 1 if the Holt-Laury list experiment was played first; 0 otherwise. In table 7, the coefficient estimate on the 'Holt-Laury First' is not statistically significant from zero. Thus, evidence is not strong enough to support the existence of order effects in any direction in our experimental setting.

5.2.3 Prospect theory

Kahneman and Tversky (1979) developed the prospect theory as an alternative to the expected utility theory in order to explain decision making under uncertainty. According to the prospect theory, people interpret outcomes as gains and losses relative to some reference point. We are interested in testing whether individuals behave according to the predictions of the prospect theory. Specific predictions to be tested are the following: First, the value function is steeper for losses than for gains, i.e., individuals get hurt more by losses than they gain from gains. Second, the value function is concave for gains and convex for losses, i.e., individuals are risk-averse over gains and risk-seeking over losses. Third, individuals tend to overweigh outcomes with low probabilities.

As there is no way of testing where the reference point is, we would like to first use a reference point of zero profit in the previous round, i.e., a positive (negative) profit in the previous round is considered as a gain (loss). Table 9 shows the result. Column 1 only contains the magnitudes of lagged gains and losses, and column 2 contains both the magnitudes and the squared magnitudes of lagged gains and losses. Both the columns 1 and 2 in table 9 indicate that individuals produce more (less) after making a positive (negative) profit in the previous round. First, we can observe that individuals who made a positive (negative) profit in the previous round tend to increase (decrease) production. Given that the size of the coefficient estimate is greater for the magnitude of the gain than for the magnitude of the loss, we cannot find evidence of the prediction that the value function is steeper for losses than for gains. Looking at the squared terms of the gains and losses that are

[4] In our experiments, payoffs were summed up and paid at the end of the session, after both experiments were conducted. Therefore, having completed only the first part of the session, subjects were not paid cash yet. But the mere idea of having earned some money in the first part of the session may affect choices in the latter part of the session.

negative and positive, respectively, we can see that the second prediction can be supported by our results−the value function seems to be concave for gains and convex for losses.

Table 10 shows how subjects react to moderate and extreme outcomes. In columns 1 and 2, a lagged profit of ±4.76 was picked as thresholds.[5] In column 1, the base case is having had a negative profit in the previous round. Dummy variables are created for having a profit greater than 4.76 (extreme outcome) and a profit between 0 and 4.76 (moderate outcome). Column 1 shows that having had a positive profit in the previous round increases the production level compared to the situation of having had a negative profit. It is also shown that subjects increase the production level by a greater degree after having a profit greater than 4.76 compared to having a profit between 0 and 4.76. In column 2, the base case is having had a positive profit in the previous round. We can see that having had a negative profit decreases production level, and having had a profit less than -4.76 (extreme outcome) decreases production level by a greater amount than having had a profit between -4.76 and 0 (moderate outcome). In columns 3 and 4, a lagged profit of ±15 was picked as threshold values. We can again see that subjects react more to extreme outcomes than to moderate outcomes in the previous round. Especially, having had a previous profit greater than 15 increases the level of production by more than 3 units compared to the case of making a loss.

All in all, our results support some predictions of the prospect theory while rejecting some others. Based on our results, subjects tend to behave consistently with the prospect theory by overweighing events with low probabilities and being risk-averse over gains and risk-seeking over losses. However, subjects tend to react more to gains than to losses, which is inconsistent with the prospect theory.

5.2.4 Safety-First

Under safety-first rule, individuals make decisions in order to avoid disaster (Telser 1995; Bigman 1996). In this paper, we are interested in figuring out: (1) whether price ambiguity makes individuals to make safety-first choices; and (2) what makes individuals to follow (or deviate from) the safety-first decision-making rule.

We define safety-first decision making as choosing a production level in order to minimize the possibility of making a loss. Following this definition, choosing a production level between 5 and 15 is equivalent to making a safety-first choice in our setup. Table 11 shows regression results with an indicator for safety-first choices as a dependent variable. The dependent variable is 1 if a subject made a safety-first choice, and 0 if not. From both columns 1 and 2, we can see that price ambiguity causes individuals to deviate from safety-first choices. Column 1 shows that making a loss in the previous round induces individuals to make safety-first choices, but it is not significant in column 2 where session dummies are included. On the other hand, making a positive profit (gain)

[5] In a given round, a profit can range from -47.58 to 32.61. 4.76 was naturally picked as a threshold for a high profit given that 4.76 is the amount of profit when price is $7 and production level is 10 which is the optimal level of production when price is $7.

in the previous round causes individuals to deviate from making safety-first choices. The coefficient estimate on 'underestimation' is positive and significant, which means that, having seen a price that is greater than what was expected in the previous round, subjects make safe choices in the current round, which is also consistent with gambler's fallacy. Greater degree of income risk aversion (switch) is significantly related with making safer choices in column 1, but it is not significant in column 2. Lastly, subjects in Peru (session 4) significantly deviated from making safe choices.

5.3 Differences across Contexts

Recall that different sessions were conducted in different dates and locations. Sessions 1 and 2 were conducted at Cornell University in December 2014 and March 2015, respectively, and session 3 was conducted at the University of Minnesota in October 2015. Session 4 was conducted in rural Peru during August-September 2016. Subjects in sessions 1 through 3 were undergraduate students, and subjects in session 4 were smallholder farmers in rural Peru.

Table 12 shows whether there is any differential effect of price ambiguity and cumulative average prices by session, using interaction terms. In column 1, the base case is session 4 conducted in Peru. We can see that, given price uncertainty, subjects in session 1 decreased production level, whereas subjects in session 2 increased it. There was no differential effect of session 3 participants given uncertainty. In column 2, the base case is sessions 1-3 in which students in the U.S. participated as subjects. Column 2 shows that, farmers in rural Peru tend to produce more under uncertainty compared to students in the U.S. Comparing the coefficients on uncertainty in columns 1 and 2, we can see that positive and significant impact of uncertainty on production was driven by participants in sessions 2 and 4. Cumulative average price has positive and significant coefficient in both columns 1 and 2, and we do not observe differential effect of sessions.

Table 13 shows results by each session. Again, subjects in session 1 decreased production under uncertainty, but subjects in sessions 2 and 4 increased production under uncertainty. Participants in session 3 neither significantly increased nor decreased production under uncertainty. Negative coefficient on underestimation, which suggests a gambler's fallacy, is consistent across all sessions, although not significant in session 3.

Why do we observe different patterns of production choices under price ambiguity according to sessions? Comparing the prices drawn in sessions 1-4 shown in tables 3-6, we can see that the average price was higher for session 2, but the difference is not statistically significant. Figure 4 shows histograms of only the prices drawn under uncertainty during practice rounds (rounds 1-10) by session. We can see that only low prices (5 or 7) were drawn in session 1 and only high prices (7, 8, or 9) were drawn in session 2. Suspecting that the different prices drawn might have affected the priors formed by subjects in sessions 1 and 2, we intentionally drew prices from a uniform distribution without replacements in session 3 during practice rounds. In session 4 in which prices in all rounds were randomly drawn for each subject, the distribution resembles a normal distribution

in figure 2 which ping pong balls were drawn from.

Figure 5 compares production choices during real rounds (rounds 11-30) under uncertainty by session. We can see that in session 3 in which prices were drawn from a uniform distribution during practice rounds, subjects chose to produce at 10 (optimal production level when price is 7) in 39% of all subject-round observations. We can also see that the distribution of production choices is a lot more spread out for session 4. Figure 6 shows scatter plots of cumulative average prices by session, and figure 7 shows the difference between actual and optimal production level by session. A positive (negative) difference indicates that subjects on average produced more (less) than the optimal level based on the cumulative average price. According to the cumulative average prices that increases (decreases) over time in session 1 (session 2), we can see that subjects adjust their production levels from above (below) in session 1 (session 2). In sessions 3 and 4, subjects tend to produce more than the optimal level throughout the rounds. Figures 8 through 11 show the plots of the difference between actual and optimal production level by each individual for sessions 1 through 4.

Another notable difference across context is the switch point during the Holt-Laury list experiment. Subjects in sessions 1-3 switched from option A to option B in row 7 on average, 6 safe choices. This corresponds to having the coefficient of relative risk aversion between 0.41 and 0.68, or being risk averse (Holt and Laury, 2002). This is very similar to the degree of risk aversion Holt and Laury (2002) finds for students in the U.S. using the same amount of payoffs. From table 6, we can see that subjects in session 4 switched in row 3 on average. This corresponds to having the coefficient of relative risk aversion between -0.95 and -0.49 (very risk loving). Thus, we find that farmer subjects who participated in session 4 are much more risk loving than what was found by Warnick et al. (2011) for Peruvian farmers[6] and what Cardenas and Carpenter (2008) summarized as findings for subjects in developing countries.

Again, subjects in sessions 2 and 4 significantly increased production levels under price ambiguity. We conjecture that the behavior of subjects in sessions 2 is associated with unusually high prices drawn during the practice round in session 2, and also that the results in session 4 is largely driven by subjects' risk-loving attitudes.

5.4 Risk Attitudes and Production Decisions

Sandmo (1971) predicted that, under price risk, risk-averse producers would decrease the level of production compared to the situation of price certainty. How would risk-averse producers behave under price ambiguity? Table 14 shows regression results with interaction terms for risk attitudes. Column 1 includes results with interaction terms involving an indicator for risk-aversion,[7] and

[6] Warnick et al. (2011) used a measure to elicit risk aversion inspired by Eckel and Grossman (2008), and found that the corresponding range of risk aversion of Peruvian farmers is between 0.27 and 0.48.

[7] The indicator for risk-aversion was created following Holt-Laury's (2002) range of relative risk aversion. The value is 1 if a subject has made 5 or more safe choices in the list experiment; 0 otherwise.

column 2 includes interaction terms involving the row number in which a subjects switched from a safe to a risky choice. We do not see a differential effect of price ambiguity or cumulative average price on the level of production when the indicator for risk aversion was used. However, column 2 shows that, given price ambiguity, a greater degree of risk aversion significantly decreases production levels. Or, given one's risk attitude, price ambiguity significantly decreases production. We can also see that, given a cumulative average price, greater risk aversion significantly decreases production level.

Table 15 shows the results for risk-averse (column 1) and risk-neutral to risk-loving (column 2) subsamples separately. We can see that the increased production level under price ambiguity is driven by risk-neutral and risk-loving subjects. Risk-averse subjects tend to slightly decrease production under price ambiguity although it is not statistically significant. Both risk-averse and risk-neutral to risk-loving subjects update production levels according to cumulative average prices and significantly increase production level as rounds proceed. We see evidence of gambler's fallacy from both subsamples.

5.5 Robustness Checks

In the lab-in-the-field experiments in Peru, we included a set of survey questions asking whether subjects could understand the experiments. Among 48 subjects participated in session 4 (experiments in Peru), 5 individuals and 3 individuals reported that they could not understand the price ambiguity game and Holt-Laury list game, respectively.[8] Columns 1 and 2 of table 16 report results from excluding the 8 individuals who self-reported that they could not understand either the price ambiguity experiment or the Holt-Laury list experiment, without and with session dummies. Our basic results are robust to the exclusion of the subjects who admitted lack of understanding.

From the charts provided to the subjects, we can see that producing at 1, 2, 3, or 20 units are not rational given any price scenario.[9] There are 4 individuals among the U.S. student subjects and 17 among the Peruvian farmer subjects who produced at these levels during real rounds. Columns 3 and 4 show the results excluding the 8 subjects who self-reported their lack of understanding and the 21 subjects who made the irrational choices,[10] without and with session dummies. We can see that the effect of price ambiguity, although still positive in sign, become insignificant. Cumulative average price is still positive, although it becomes insignificant due to a high standard error when session dummies are included.[11]

All in all, when the subjects who self-reported their lack of understanding of the experiments

[8] The groups of individuals that self-reported their lack of understanding of the two games do not overlap.

[9] For example, at any given price level, producing at 4 yields a higher profit than producing at 1, 2, or 3; Likewise, producing at 19 always yields a higher profit than producing at 20 at any given price.

[10] There are two subjects who both self-reported their lack of understanding and were spotted as irrational. Thus, a total of 27 subjects were excluded.

[11] The p-value on the cumulative average price is 0.147.

are excluded, our basic results are robust. When we exclude the subjects who made irrational choices during real rounds of the price ambiguity game as well, uncertainty becomes insignificant and cumulative average price becomes marginally significant. Our findings on gambler's fallacy is robust, and greater degree of risk aversion consistently decreases production.

5.6 Limitations

This study is not without its limitations. Our results indicate that production level is increased under price ambiguity. There might be a possibility that this result was driven by the 'house-money effect,' a tendency that investors buy riskier assets after making a profitable trade (Thaler and Johnson, 1990). We had to guarantee some fixed amount of remunerations to our participants in order to compensate for their time. Thus, student subjects received 45 USD and 45 PEN for participation. These are the amounts of money that participants received regardless of their performance in price ambiguity experiment and the Holt-Laury List experiment. To minimize the possibility that subjects think that they have earned some positive profits to gamble during the experiments and take high risks, we mentioned during the instructions that subjects receive the fixed payments "for their time for participation and also for filling out demographic questions." But with our experimental design, we could neither eliminate nor test the possibility of the house money effect.

6 Concluding Remarks

We generate experimental data from unique production game designed to study decision making under price ambiguity. Our results from the pooled sample indicate that subjects increase production levels under price ambiguity, but when we examine the subsamples, we find that the results were driven by two factors: information on past prices and risk attitudes. First, priors on prices formed during practice sessions seem to matter. In sessions 1 and 2 in which experimenters accidentally drove low and high prices during practice sessions, respectively, subjects decreased and increased production levels under price ambiguity. In session 3 where prices were drawn from a uniform distribution without replacements, price ambiguity had no significant impact on production. Second, this result is also driven by risk-loving subjects based on the risk attitude elicitation from Holt-Laury list experiments. Also, participants in our lab-in-the-field experiments in Peru exhibited risk-loving tendency and produced significantly high levels of output during price ambiguity. Thus, we find that subjects' risk attitudes play an important role in making production decisions.

How do subjects incorporate price information when making production decisions? We observe that subjects rationally incorporate and update price information following the cumulative average of past prices. We find evidence that subjects incorporate all the past price information, but most current price information matter more than older information which is similar to what Mattos and Zinn (2016) find for producers' marketing decisions in Canada.

We examine whether people resort to heuristics when making production decisions with very limited information. We find very consistent and strong evidence of gambler's fallacy. We also find some behavior consistent with prospect theory−subjects react more to extreme values of profits in the previous rounds.

What can we learn from the findings in this paper in conjunction with the findings in Bellemare et al. (2017)? Bellemare et al. (2017) conducts experiments that are almost identical to the experiments in this study. But in Bellemare et al. (2017) subjects know price distributions. Under the situation of price risk not price ambiguity, subjects significantly increase production at an extensive margin but decrease production in response to price risk at the intensive margin. In our experimental setup in which subjects do not know price distributions, contexts matter and past price information form expectations for future prices. Also, law of small numbers and producer's risk attitudes dictate production decisions.

There is a possibility that subjects may have increased their production levels under price ambiguity due to the fixed payoffs that they received for participation, which is a limitation of this study. In that spirit, making the following changes to the price ambiguity experiments conducted in this paper can be interesting to pursue for future studies: First, with a varying amounts of participation payoffs, we could test whether there is a house money effect. Second, introducing an opportunity to purchase insurance products or a requirement to satisfy a subsistence level of profits (below which, for example, subjects "die" and should drop out of the session) and investigating how production decisions are affected might be topics worth exploring.

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7 Tables and Figures

Figure 1. Structure of the Production Game

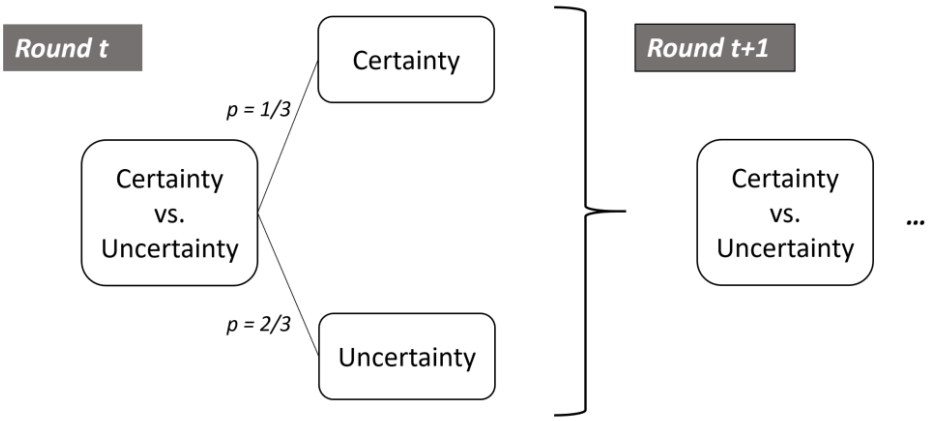


Figure 2. Bag of 80 Balls

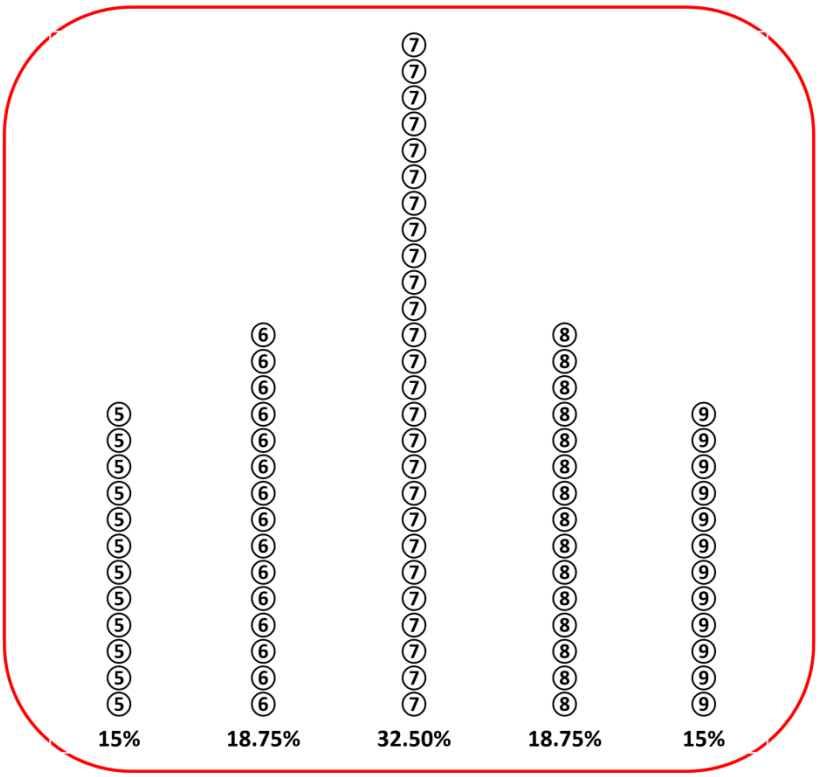


Figure 3. Production under Uncertainty, All Sessions, Real Rounds (Rounds 11-30)

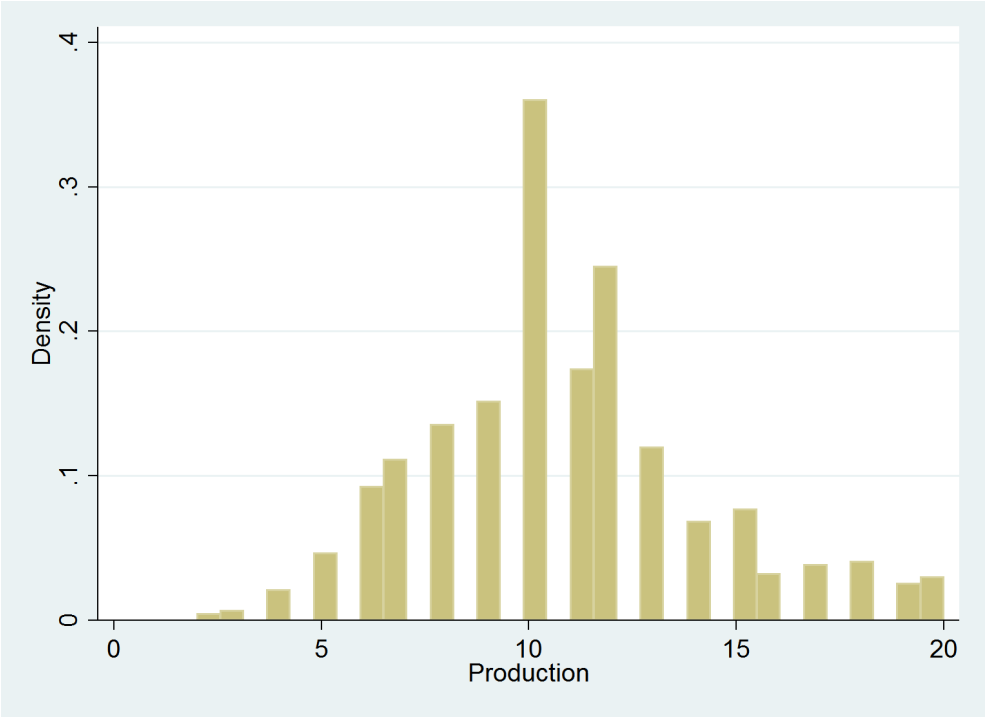


Figure 4. Prices Drawn under Uncertainty During Practice Rounds (Rounds 1-10), by Session

Figure 5. Production under Uncertainty During Real Rounds (Rounds 11-30), by Session

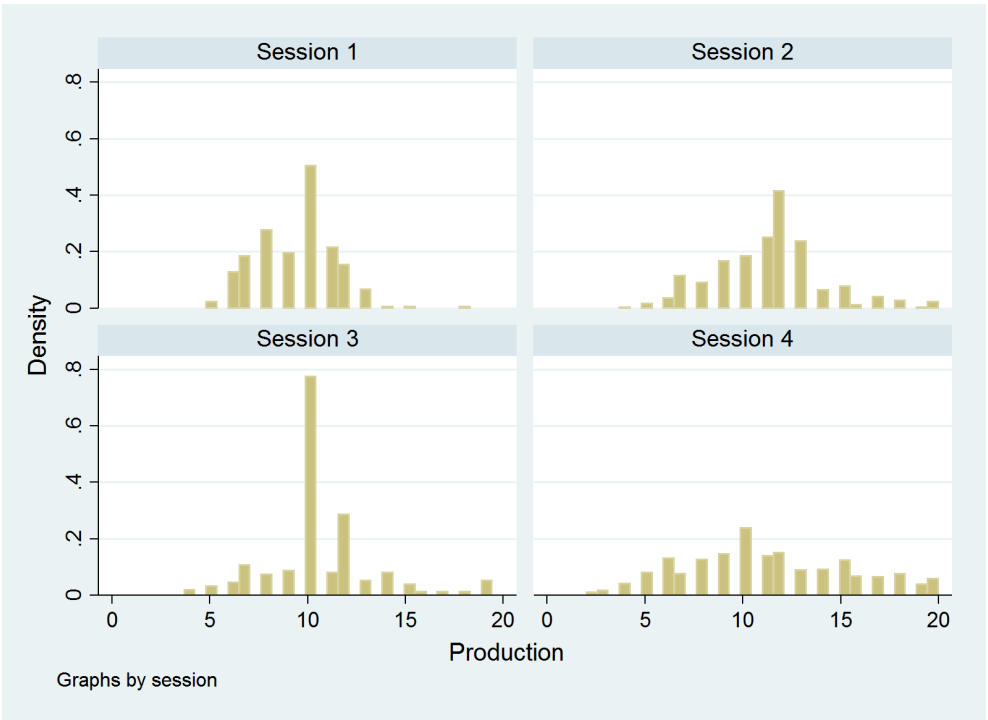


Figure 6. Cumulative Average Price, by Session

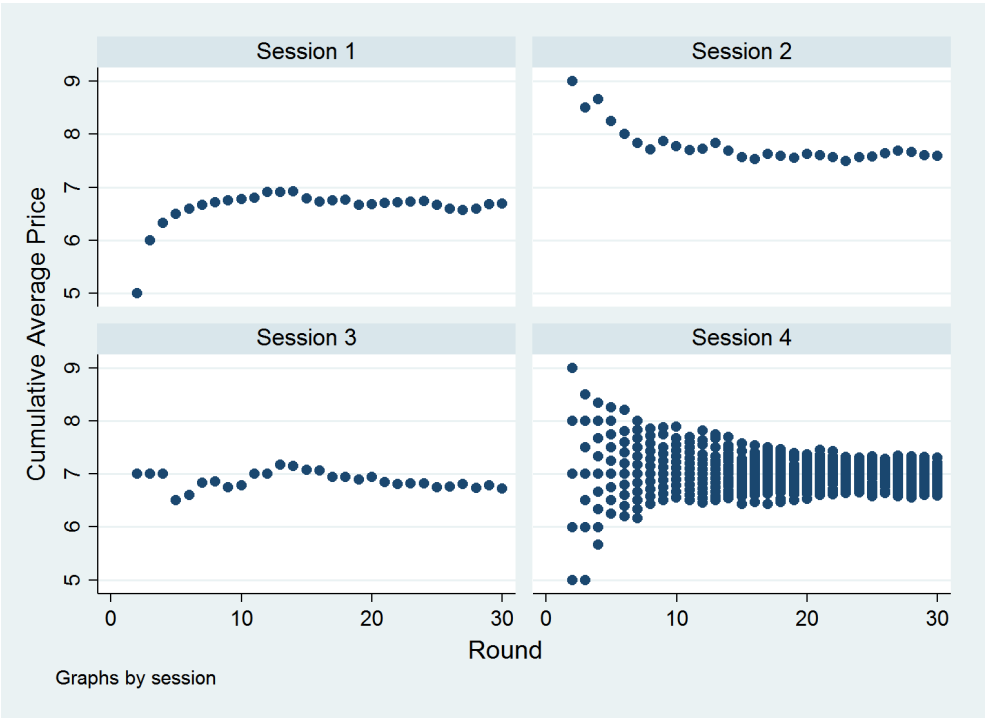


Figure 7. Actual vs. Optimal Production under Uncertainty, by Session

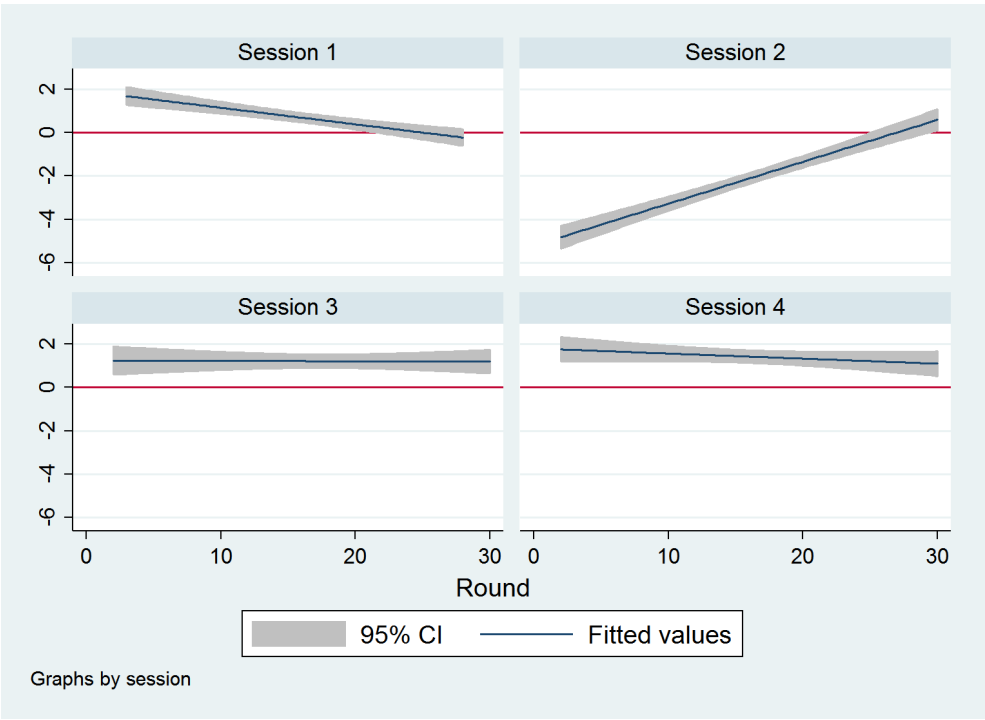


Figure 8. Actual vs. Optimal Production under Uncertainty, by ID: Session 1

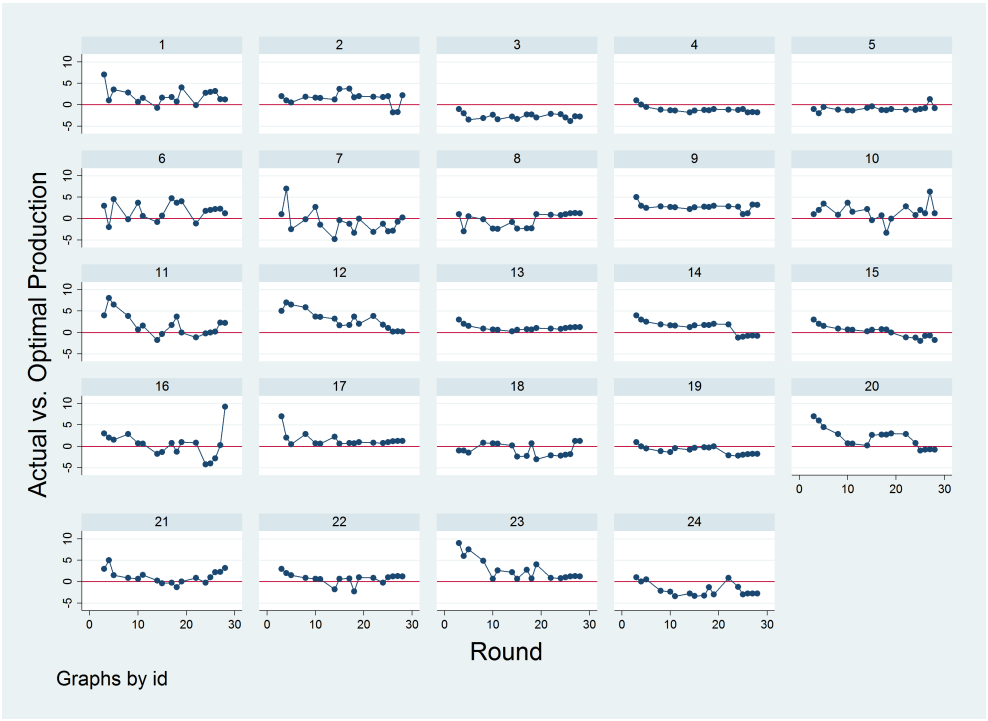


Figure 9. Actual vs. Optimal Production under Uncertainty, by ID: Session 2

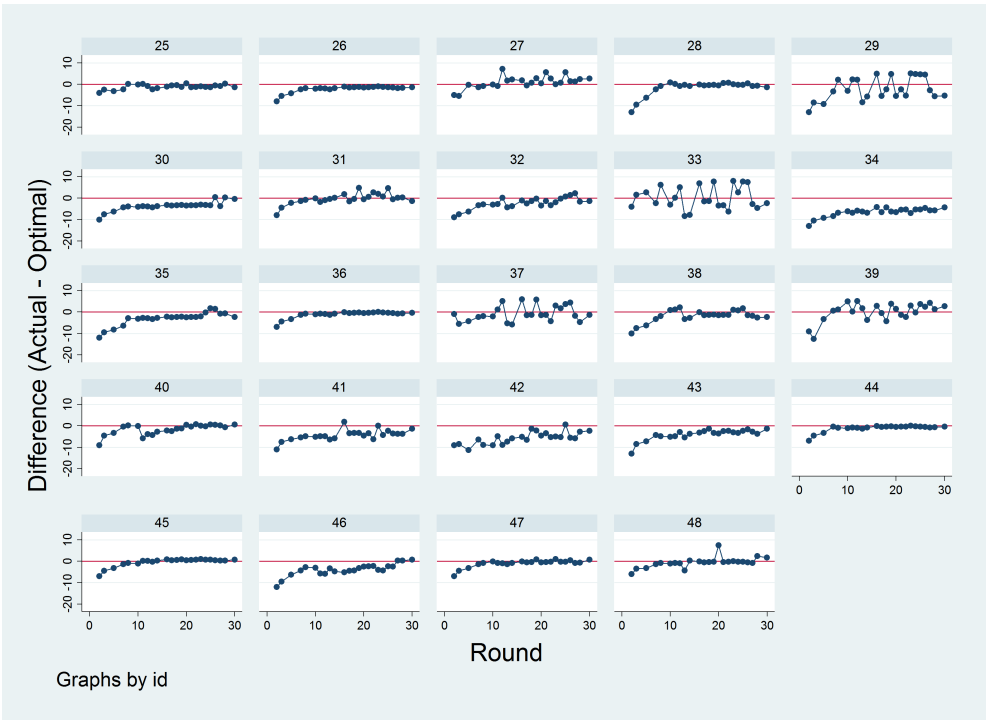


Figure 10. Actual vs. Optimal Production under Uncertainty, by ID: Session 3

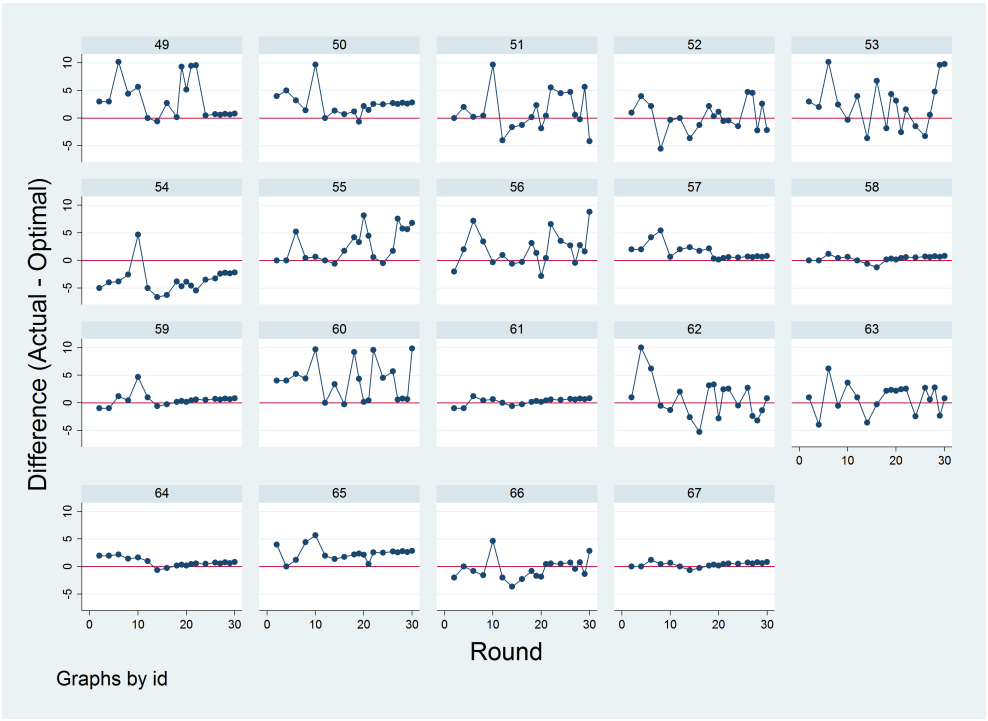


Figure 11. Actual vs. Optimal Production under Uncertainty, by ID: Session 4

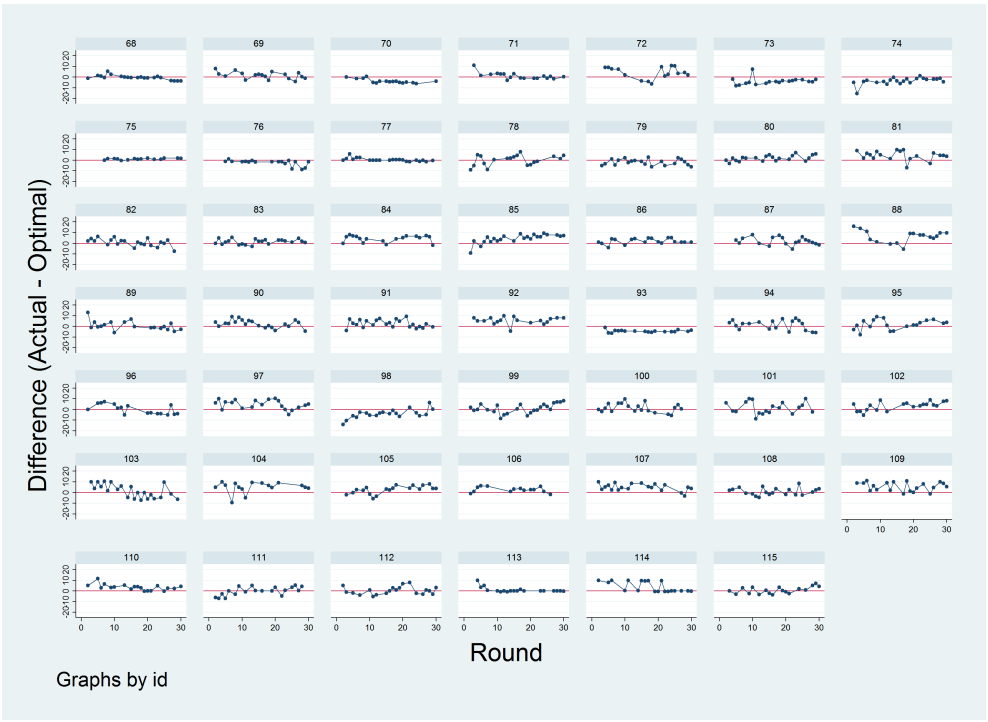


Table 1. Experimental Setup

Session	Date	Location	N. of Subjects	Order of Games
1	Dec. 2014	Cornell LEEDR Lab	24	Production - HL
2	Mar. 2015	Cornell LEEDR Lab	24	HL - Production
3	Oct. 2015	Univ. of Minnesota	19	HL - Production
4	Aug.-Sep. 2016	Peru	48	Random

Table 2. Summary Statistics for the Pooled Sample (N =3,450)

Variable	Mean	Std. Dev.	Min.	Max.
Production (0 to 20)	10.762	3.099	1	20
Uncertainty (0 or 1)	0.680	0.467	0	1
Price (5,6,7,8,9)	7.009	1.075	5	9
Holt-Laury Switch Point (1 to 10)	5.304	2.589	1	10
Age (years)	31.991	16.503	18	73
Female (0 or 1)	0.456	0.498	0	1
Holt-Laury First (0 or 1)	0.557	0.497	0	1
Profit (-47.58 to 32.61)	3.831	12.55	-47.578	32.609

Table 3. Summary Statistics for Session 1 (N =720)

Variable	Mean	Std. Dev.	Min.	Max.
Production (0 to 20)	9.693	1.766	3	18
Uncertainty (0 or 1)	0.6	0.49	0	1
Price (5,6,7,8,9)	6.7	0.901	5	9
Holt-Laury Switch Point (1 to 10)	6.792	1.959	4	10
Age (years)	20.652	0.915	19	23
Female (0 or 1)	0.609	0.488	0	1
Profit (-47.58 to 32.61)	1.633	8.588	-22.536	32.604

Table 4. Summary Statistics for Session 2 (N =720)

Variable	Mean	Std. Dev.	Min.	Max.
Production (0 to 20)	10.922	2.63	4	20
Uncertainty (0 or 1)	0.833	0.373	0	1
Price (5,6,7,8,9)	7.567	1.055	6	9
Holt-Laury Switch Point (1 to 10)	7.083	1.802	4	10
Age (years)	20.792	1.684	18	25
Female (0 or 1)	0.583	0.493	0	1
Profit (-47.58 to 32.61)	10.411	12.032	-13.625	32.609

Table 5. Summary Statistics for Session 3 (N =570)

Variable	Mean	Std. Dev.	Min.	Max.
Production (0 to 20)	10.521	2.336	4	20
Uncertainty (0 or 1)	0.633	0.482	0	1
Price (5,6,7,8,9)	6.733	1.124	5	9
Holt-Laury Switch Point (1 to 10)	6.158	1.388	4	9
Age (years)	19.895	1.295	18	23
Female (0 or 1)	0.158	0.365	0	1
Profit (-47.58 to 32.61)	1.379	12.673	-47.578	32.609

Table 6. Summary Statistics for Session 4 (N =1440)

Variable	Mean	Std. Dev.	Min.	Max.
Production (0 to 20)	11.313	3.864	1	20
Uncertainty (0 or 1)	0.662	0.473	0	1
Price (5,6,7,8,9)	6.994	1.038	5	9
Holt-Laury Switch Point (1 to 10)	3.333	2.212	1	9
Age (years)	47.813	14.552	20	73
Female (0 or 1)	0.438	0.496	0	1
Holt-Laury First (0 or 1)	0.438	0.496	0	1
Profit (-47.58 to 32.61)	2.609	13.3	-47.578	32.609

Table 7. Main Results
Dependent Variable: Level of Production (0-20)

	(1)	(2)	(3)	(4)	(5)
Uncertainty	0.571***	0.556***	0.568***	0.494**	0.467**
	(0.215)	(0.214)	(0.214)	(0.217)	(0.224)
Cumulative Avg. Price		1.192***	1.166***	1.710***	1.683*
		(0.394)	(0.405)	(0.390)	(0.889)
Cumulative Variance			0.301	0.0700	-0.131
			(0.418)	(0.514)	(0.537)
Underestimation				-0.316***	-0.391***
				(0.0592)	(0.0654)
Switch		-0.169***	-0.167***	-0.166***	-0.134*
		(0.0548)	(0.0555)	(0.0507)	(0.0800)
Round		0.0346**	0.0312*	0.0364***	0.0378**
		(0.0142)	(0.0170)	(0.0141)	(0.0162)
Female		-0.402	-0.395	-0.360	-0.335
		(0.285)	(0.285)	(0.262)	(0.280)
Holt-Laury First				0.00796	-0.0792
				(0.374)	(0.541)
Session 2					0.310
					(1.135)
Session 3					0.333
					(0.756)
Session 4					0.403
					(0.626)
Constant	10.21***	2.180	2.121	-1.608	-1.665
	(0.0925)	(2.746)	(2.709)	(2.640)	(6.118)
N	2300	2280	2280	2280	2280
R^2	0.0103	0.0604	0.0607	0.0866	0.0883

Standard errors in parentheses

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

Table 8. Moving Average Prices
Dependent Variable: Level of Production (0-20)

	(1)	(2)	(3)	(4)	(5)
Uncertainty	0.494**	0.648***	0.656***	0.612***	0.625***
	(0.212)	(0.201)	(0.201)	(0.198)	(0.204)
Cumulative Avg. Price	1.715***				
	(0.356)				
4-rounds M.A.		1.097***			
		(0.147)			
3-rounds M.A.			0.965***		
			(0.128)		
2-rounds M.A.				0.935***	
				(0.121)	
Price L.1					1.428***
					(0.133)
Cumulative Variance	0.0746	0.356	0.424	0.471	0.429
	(0.417)	(0.381)	(0.376)	(0.365)	(0.295)
Underestimation	-0.317***	-0.471***	-0.515***	-0.624***	-1.304***
	(0.0588)	(0.0677)	(0.0715)	(0.0859)	(0.124)
Switch	-0.166***	-0.139***	-0.133***	-0.125***	-0.103***
	(0.0508)	(0.0454)	(0.0446)	(0.0431)	(0.0336)
Round	0.0363***	0.0268**	0.0248**	0.0206*	0.0200**
	(0.0140)	(0.0125)	(0.0125)	(0.0121)	(0.0101)
Female	-0.361	-0.309	-0.305	-0.282	-0.186
	(0.266)	(0.248)	(0.246)	(0.241)	(0.194)
Constant	-1.642	2.438**	3.299***	3.515***	-0.111
	(2.351)	(1.102)	(0.998)	(0.964)	(1.015)
N	2280	2280	2279	2279	2280
R^2	0.0866	0.0946	0.0931	0.0998	0.1609

Standard errors in parentheses

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

Table 9. Gains and Losses
Dependent Variable: Level of Production (0-20)

	(1)	(2)
Uncertainty	0.459**	0.427*
	(0.222)	(0.222)
Cumulative Avg. Price	0.808	0.760
	(0.727)	(0.705)
Cumulative Variance	-0.0320	0.0628
	(0.459)	(0.446)
Loss Magnitude L.1	-0.0904***	-0.132***
	(0.0163)	(0.0289)
Loss Magnitude L.1 Squared		0.00186**
		(0.000860)
Gain Magnitude L.1	0.109***	0.193***
	(0.0121)	(0.0358)
Gain Magnitude L.1 Squared		-0.00283**
		(0.00112)
Underestimation	-1.143***	-1.235***
	(0.114)	(0.120)
Switch	-0.0973	-0.0965
	(0.0630)	(0.0610)
Round	0.0276**	0.0277**
	(0.0138)	(0.0135)
Female	-0.206	-0.211
	(0.225)	(0.218)
Holt-Laury First	-0.0774	-0.0658
	(0.441)	(0.427)
Session 2	0.454	0.502
	(0.907)	(0.873)
Session 3	0.336	0.278
	(0.614)	(0.585)
Session 4	0.595	0.545
	(0.506)	(0.488)
Constant	3.713	3.795
	(4.966)	(4.826)
N	2280	2280
R^2	0.1587	0.1666

Standard errors in parentheses

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

Table 10. Extreme Outcomes
Dependent Variable: Level of Production (0-20)

	Threshold ±4.76		Threshold ±15	
	(1)	(2)	(3)	(4)
Uncertainty	0.366*	0.395*	0.412*	0.387*
	(0.220)	(0.219)	(0.223)	(0.222)
Cumulative Avg. Price	1.280	1.422*	1.044	1.422*
	(0.821)	(0.818)	(0.756)	(0.826)
Cumulative Variance	0.103	0.227	-0.0295	0.192
	(0.497)	(0.508)	(0.459)	(0.515)
4.76 <Profit L.1	1.696***			
	(0.212)			
0 < Profit L.1 < 4.76	0.994***			
	(0.191)			
-4.76 < Profit L.1 < 0		-1.021***		
		(0.225)		
Profit L.1 < -4.76		-1.601***		
		(0.241)		
15 <Profit L.1			3.189***	
			(0.307)	
0 < Profit L.1 < 15			1.342***	
			(0.175)	
-15 < Profit L.1 < 0				-1.357***
				(0.177)
Profit L.1 < -15				-1.547***
				(0.342)
Underestimation	-0.766***	-0.751***	-0.917***	-0.721***
	(0.0870)	(0.0930)	(0.0896)	(0.0926)
Switch	-0.122*	-0.125*	-0.106*	-0.122*
	(0.0708)	(0.0732)	(0.0636)	(0.0728)
Round	0.0335**	0.0355**	0.0293**	0.0357**
	(0.0151)	(0.0154)	(0.0142)	(0.0155)
Female	-0.267	-0.295	-0.238	-0.287
	(0.254)	(0.257)	(0.230)	(0.258)
Holt-Laury First	-0.0739	-0.0687	-0.0146	-0.0814
	(0.492)	(0.498)	(0.457)	(0.501)
Constant	-0.201	0.261	1.376	0.239
	(5.642)	(5.634)	(5.183)	(5.692)
Session Dummies	Yes	Yes	Yes	Yes
N	2280	2280	2280	2280
R^2	0.1201	0.1145	0.1528	0.1130

Standard errors in parentheses

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

Table 11. Safety First
Dependent Variable: Safety First Production (0 or 1)

	(1)	(2)
Uncertainty	-0.108***	-0.109***
	(0.0166)	(0.0168)
Cumulative Avg. Price	0.00254	-0.0439
	(0.0297)	(0.0642)
Cumulative Variance	-0.0394	-0.00848
	(0.0348)	(0.0370)
Loss Magnitude L.1	0.00246*	0.00239
	(0.00146)	(0.00146)
Gain Magnitude L.1	-0.00334***	-0.00364***
	(0.000955)	(0.000942)
Underestimation	0.0293***	0.0326***
	(0.00927)	(0.00929)
Switch	0.0127***	-0.00387
	(0.00379)	(0.00431)
Round	-0.000469	-0.00117
	(0.00122)	(0.00135)
Female	-0.0340*	-0.0305
	(0.0204)	(0.0199)
Holt-Laury First	0.00646	-0.00809
	(0.0283)	(0.0407)
Session 2		0.0449
		(0.0878)
Session 3		-0.0174
		(0.0557)
Session 4		-0.132***
		(0.0418)
Constant	0.986***	1.446***
	(0.208)	(0.447)
N	2280	2280
R^2	0.0635	0.0980

Standard errors in parentheses

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

Table 12. Results by Contexts
Dependent Variable: Level of Production (0-20)

	(1)	(2)
Uncertainty	0.863**	0.130
	(0.365)	(0.244)
Uncertainty × Session 1	-1.801***	
	(0.476)	
Uncertainty × Session 2	1.176**	
	(0.499)	
Uncertainty × Session 3	-0.385	
	(0.548)	
Uncertainty × Session 4		0.734*
		(0.439)
Cumulative Avg. Price	1.657*	1.861***
	(0.875)	(0.395)
Cumulative Avg. Price × Session 1	0.102	
	(0.0862)	
Cumulative Avg. Price × Session 2	-0.159	
	(0.0998)	
Cumulative Avg. Price × Session 3	0.0231	
	(0.0568)	
Cumulative Avg. Price × Session 4		-0.0451
		(0.0500)
Cumulative Variance	-0.114	-0.0101
	(0.536)	(0.526)
Underestimation	-0.460***	-0.389***
	(0.0644)	(0.0620)
Holt-Laury First	-0.0840	0.0477
	(0.535)	(0.372)
Switch	-0.132*	-0.144*
	(0.0787)	(0.0778)
Round	0.0382**	0.0390***
	(0.0160)	(0.0139)
Female	-0.325	-0.360
	(0.276)	(0.259)
Constant	-1.394	-2.613
	(6.270)	(2.715)
N	2280	2280
R^2	0.1051	0.0909

Standard errors in parentheses

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

Table 13. Results by Contexts
Dependent Variable: Level of Production (0-20)

	(1)	(2)	(3)	(4)
	Session 1	Session 2	Session 3	Session 4
Uncertainty	-0.752**	1.641***	0.639	0.883**
	(0.331)	(0.242)	(0.473)	(0.365)
Cumulative Avg. Price	1.739	-4.311	-1.997	1.477
	(1.290)	(3.165)	(2.312)	(1.045)
Cumulative Variance	0.446	-3.286	2.462	-0.246
	(0.985)	(2.156)	(2.223)	(0.530)
Underestimation	-0.287***	-0.242**	-0.173	-0.423***
	(0.0880)	(0.106)	(0.130)	(0.0996)
Holt-Laury First	-	-	-	-0.269
	-	-	-	(0.582)
Switch	-0.0309	-0.558***	-0.198	-0.0181
	(0.0974)	(0.138)	(0.146)	(0.128)
Round	-0.000896	0.0818***	-0.0582	0.0402
	(0.0293)	(0.0203)	(0.0806)	(0.0270)
Female	-0.428	-0.569	-0.973	0.0890
	(0.287)	(0.372)	(1.058)	(0.512)
Constant	-1.504	48.67*	23.48	-0.524
	(9.126)	(25.48)	(15.54)	(7.279)
N	460	480	380	960
R^2	0.0831	0.2677	0.0805	0.0554

Standard errors in parentheses

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

Table 14. Results by Income Risk Attitudes
Dependent Variable: Level of Production (0-20)

	(1)	(2)
Uncertainty	0.827**	1.522***
	(0.351)	(0.470)
Cumulative Avg. Price	1.805*	2.899***
	(1.007)	(1.081)
Uncertainty × Risk Averse	-0.611	
	(0.441)	
Uncertainty × Switch		-0.212***
		(0.0811)
Cumulative Avg. Price × Risk Averse	-0.907	
	(0.966)	
Cumulative Avg. Price × Switch		-0.394**
		(0.165)
Cumulative Variance	-0.227	-0.282
	(0.523)	(0.546)
Risk Averse	6.528	
	(6.753)	
Switch		2.790**
		(1.147)
Underestimation	-0.390***	-0.357***
	(0.0669)	(0.0653)
Round	0.0343**	0.0302*
	(0.0167)	(0.0167)
Female	-0.399	-0.301
	(0.285)	(0.278)
Holt-Laury First	-0.180	-0.106
	(0.552)	(0.548)
Session 2	1.118	1.903
	(1.225)	(1.201)
Session 3	0.701	0.805
	(0.748)	(0.765)
Session 4	1.040	1.045
	(0.644)	(0.637)
Constant	-3.520	-11.27
	(6.893)	(7.497)
N	2280	2280
R^2	0.0858	0.1044

Standard errors in parentheses

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

Table 15. Results by Income Risk Attitudes
Dependent Variable: Level of Production (0-20)

	(1)	(2)
	Risk Averse	Risk Neutral, Risk Loving
Uncertainty	-0.0996	0.977***
	(0.297)	(0.284)
Cumulative Avg. Price	1.724**	2.057***
	(0.724)	(0.539)
Cumulative Variance	-1.058	0.324
	(1.014)	(0.532)
Underestimation	-0.385***	-0.293***
	(0.0893)	(0.0831)
Switch	-0.274	-0.0668
	(0.167)	(0.136)
Round	0.0404**	0.0477**
	(0.0181)	(0.0217)
Female	-0.437	-0.126
	(0.365)	(0.374)
Holt-Laury First	0.278	0.0475
	(0.873)	(0.471)
Constant	0.331	-5.233
	(5.363)	(3.787)
N	1120	1160
R^2	0.0863	0.0881

Standard errors in parentheses

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

Table 16. Robustness Checks
Dependent Variable: Level of Production (0-20)

	(1)	(2)	(3)	(4)
	Self-reported		Irrational Decisions	
Uncertainty	0.446**	0.420*	0.114	0.0595
	(0.214)	(0.225)	(0.213)	(0.228)
Cumulative Avg. Price	1.768***	1.651*	1.539***	1.166
	(0.420)	(0.916)	(0.439)	(0.804)
Cumulative Variance	-0.145	-0.428	-0.172	-0.391
	(0.451)	(0.559)	(0.417)	(0.597)
Underestimation	-0.316***	-0.347***	-0.305***	-0.305***
	(0.0587)	(0.0605)	(0.0630)	(0.0625)
Switch	-0.138***	-0.112	-0.104**	-0.158*
	(0.0529)	(0.0822)	(0.0519)	(0.0833)
Female	-0.443*	-0.377	-0.379	-0.330
	(0.259)	(0.294)	(0.279)	(0.291)
Round	0.0389***	0.0408**	0.0371***	0.0362**
	(0.0141)	(0.0168)	(0.0114)	(0.0155)
Holt-Laury First	0.0319	-0.181	0.141	-0.301
	(0.345)	(0.536)	(0.354)	(0.597)
Session 2		0.561		0.971
		(1.116)		(1.118)
Session 3		0.609		0.776
		(0.818)		(0.872)
Session 4		0.498		-0.0943
		(0.651)		(0.646)
Constant	-2.029	-1.430	-0.585	2.465
	(2.845)	(6.322)	(2.955)	(5.745)
N	2120	2120	1740	1740
R^2	0.0836	0.0853	0.0783	0.0877

Standard errors in parentheses

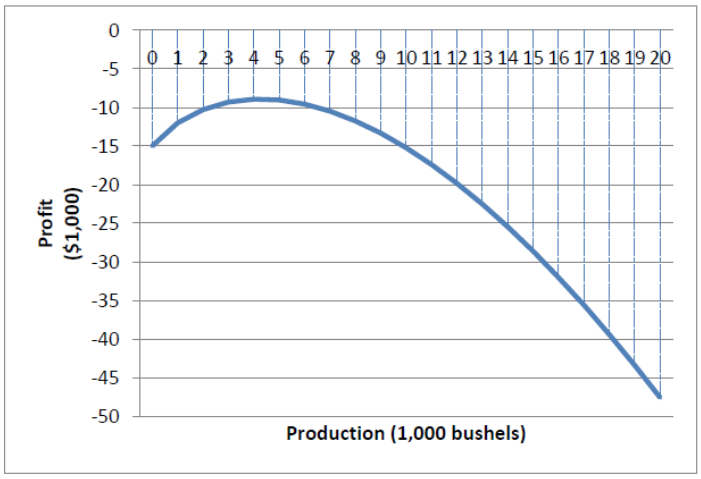
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

8 Appendices

8.1 Appendix I: Charts (English)

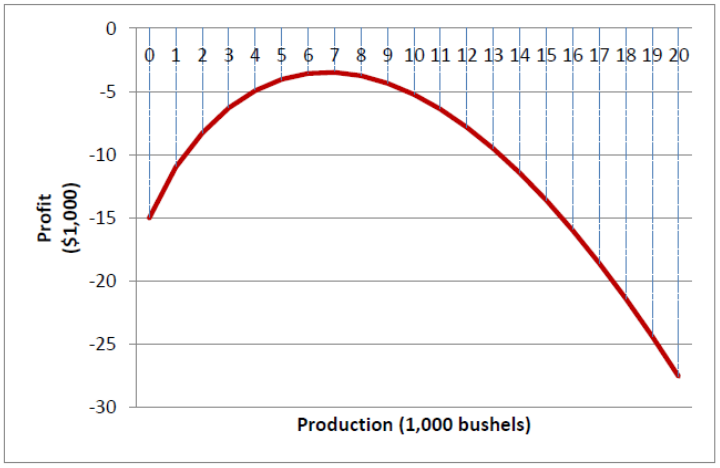
1. Wheat production, cost, and profit when price of wheat is **$5/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	5	15.00	-15.00
1	5	17.00	-12.00
2	5	20.28	-10.28
3	5	24.31	-9.31
4	5	28.93	-8.93
5	5	34.04	-9.04
6	5	39.57	-9.57
7	5	45.49	-10.49
8	5	51.76	-11.76
9	5	58.35	-13.35
10	5	65.24	-15.24
11	5	72.41	-17.41
12	5	79.85	-19.85
13	5	87.54	-22.54
14	5	95.47	-25.47
15	5	103.63	-28.63
16	5	112.01	-32.01
17	5	120.60	-35.60
18	5	129.40	-39.40
19	5	138.39	-43.39
20	5	147.58	-47.58



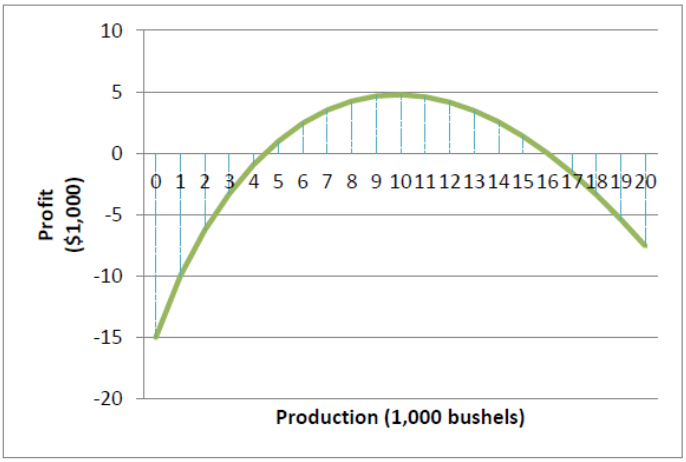
2. Wheat production, cost, and profit when price of wheat is $6/bushel.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	6	15.00	-15.00
1	6	17.00	-11.00
2	6	20.28	-8.28
3	6	24.31	-6.31
4	6	28.93	-4.93
5	6	34.04	-4.04
6	6	39.57	-3.57
7	6	45.49	-3.49
8	6	51.76	-3.76
9	6	58.35	-4.35
10	6	65.24	-5.24
11	6	72.41	-6.41
12	6	79.85	-7.85
13	6	87.54	-9.54
14	6	95.47	-11.47
15	6	103.63	-13.63
16	6	112.01	-16.01
17	6	120.60	-18.60
18	6	129.40	-21.40
19	6	138.39	-24.39
20	6	147.58	-27.58



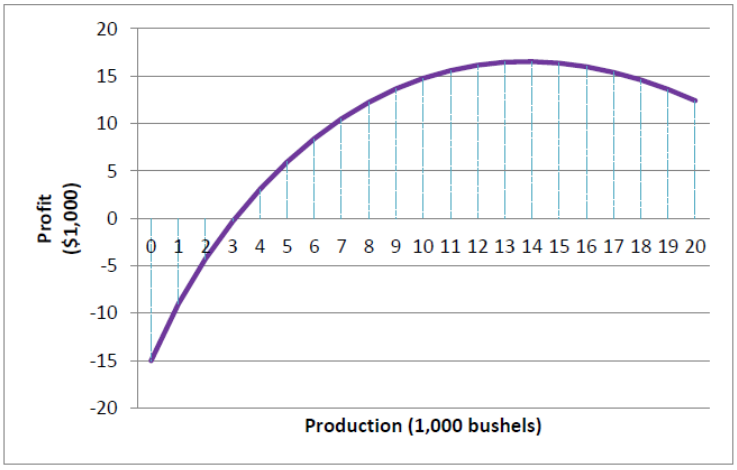
3. Wheat production, cost, and profit when price of wheat is **$7/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	7	15.00	-15.00
1	7	17.00	-10.00
2	7	20.28	-6.28
3	7	24.31	-3.31
4	7	28.93	-0.93
5	7	34.04	0.96
6	7	39.57	2.43
7	7	45.49	3.51
8	7	51.76	4.24
9	7	58.35	4.65
10	7	65.24	4.76
11	7	72.41	4.59
12	7	79.85	4.15
13	7	87.54	3.46
14	7	95.47	2.53
15	7	103.63	1.37
16	7	112.01	-0.01
17	7	120.60	-1.60
18	7	129.40	-3.40
19	7	138.39	-5.39
20	7	147.58	-7.58



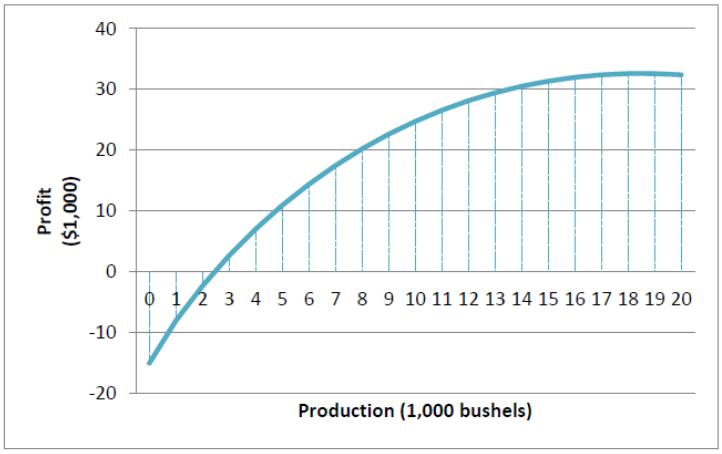
4. Wheat production, cost, and profit when price of wheat is **$8/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	8	15.00	-15.00
1	8	17.00	-9.00
2	8	20.28	-4.28
3	8	24.31	-0.31
4	8	28.93	3.07
5	8	34.04	5.96
6	8	39.57	8.43
7	8	45.49	10.51
8	8	51.76	12.24
9	8	58.35	13.65
10	8	65.24	14.76
11	8	72.41	15.59
12	8	79.85	16.15
13	8	87.54	16.46
14	8	95.47	16.53
15	8	103.63	16.37
16	8	112.01	15.99
17	8	120.60	15.40
18	8	129.40	14.60
19	8	138.39	13.61
20	8	147.58	12.42



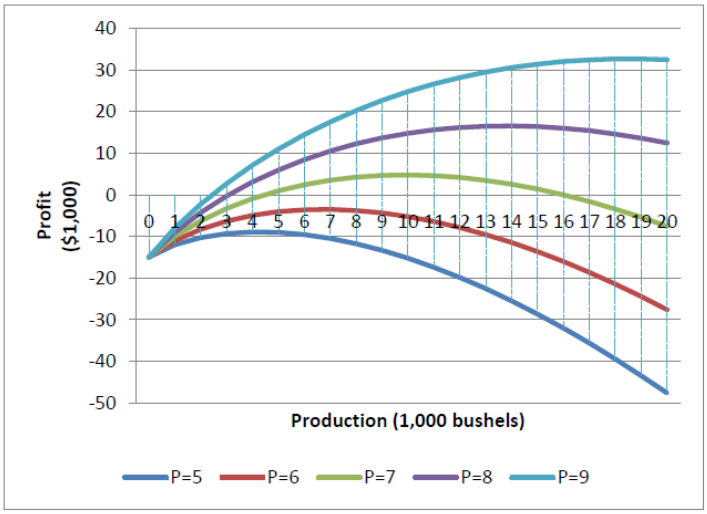
5. Wheat production, cost, and profit when price of wheat is **$9/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	9	15.00	-15.00
1	9	17.00	-8.00
2	9	20.28	-2.28
3	9	24.31	2.69
4	9	28.93	7.07
5	9	34.04	10.96
6	9	39.57	14.43
7	9	45.49	17.51
8	9	51.76	20.24
9	9	58.35	22.65
10	9	65.24	24.76
11	9	72.41	26.59
12	9	79.85	28.15
13	9	87.54	29.46
14	9	95.47	30.53
15	9	103.63	31.37
16	9	112.01	31.99
17	9	120.60	32.40
18	9	129.40	32.60
19	9	138.39	32.61
20	9	147.58	32.42



6. Profits when price of wheat is **$5/bushel-$9/bushel**.

Wheat Production	Profit				
	P = $5	P = $6	P = $7	P = $8	P = $9
0	-15.00	-15.00	-15.00	-15.00	-15.00
1	-12.00	-11.00	-10.00	-9.00	-8.00
2	-10.28	-8.28	-6.28	-4.28	-2.28
3	-9.31	-6.31	-3.31	-0.31	2.69
4	-8.93	-4.93	-0.93	3.07	7.07
5	-9.04	-4.04	0.96	5.96	10.96
6	-9.57	-3.57	2.43	8.43	14.43
7	-10.49	-3.49	3.51	10.51	17.51
8	-11.76	-3.76	4.24	12.24	20.24
9	-13.35	-4.35	4.65	13.65	22.65
10	-15.24	-5.24	4.76	14.76	24.76
11	-17.41	-6.41	4.59	15.59	26.59
12	-19.85	-7.85	4.15	16.15	28.15
13	-22.54	-9.54	3.46	16.46	29.46
14	-25.47	-11.47	2.53	16.53	30.53
15	-28.63	-13.63	1.37	16.37	31.37
16	-32.01	-16.01	-0.01	15.99	31.99
17	-35.60	-18.60	-1.60	15.40	32.40
18	-39.40	-21.40	-3.40	14.60	32.60
19	-43.39	-24.39	-5.39	13.61	32.61
20	-47.58	-27.58	-7.58	12.42	32.42



8.2 Appendix II: Instructions (English)

General Instructions

- This is an experiment in the economics of individual decision making. We are trying to understand how people make production decisions when they are unsure of the price they will receive. We have designed simple decision-making games in which we will ask you to make choices in a series of situations.
- There are two sets of games. In the first set of games, you will be making decisions assuming that you are a farmer producing a single commodity, wheat. In the second set of games, you will be given a series of lotteries to choose from. More detailed explanations will follow in each set.
- You will spend 60 to 90 minutes in this study playing economic games. You will spend about 30 minutes to receive your payment. You will receive $45 for participation and completion of the experiment and in addition may earn between $1.31 and $45.16 depending on your performance and also on the luck on the experiment.
- You should make your own decision and should not discuss your decisions or the decision scenarios with other participants. Also, please turn off your cell phones.
- You need to have a good understanding on how your decisions affect your payoff. Please raise your hand at any time during the session if you have any question.

1

Set I: Single-Commodity Production Game

- You are a farmer who produces and sells only one commodity, wheat.
- The selling price of wheat in dollars per bushel will be one of the five possible values: $5, $6, $7, $8, and $9, and it will be realized *after* you make your production decision to reflect the real-world output price uncertainty.
- You will be given charts 1 through 5 which document the amount of cost to be incurred according to production levels 0 through 20 (in 1,000 bushels), and the corresponding profit (in $1,000) that will occur *under the five different price scenarios*. These charts contain all the information about how your production decision, cost of production, and your profit relate to one another. Chart 6 is a summary of charts 1 through 5 and shows only the relationship between the production level and the profit.
- In each round, you will be given one of the two situations:

  (1) You know that your selling price will be exactly $7;

  (2) You know that the price will be one of the five values -- $5, $6, $7, $8, and $9.

  Under a given situation, you will be asked to determine how much wheat to produce by choosing any integer between 0 and 20 as your production level. You may refer to the charts 1-6 to facilitate your decision.
- Your goal is to maximize the profit (price times quantity produced minus cost of production), since maximizing profit is identical to maximizing your payoff.
- Note that there is no subsistence constraint, meaning that there is no minimum required level of production for your survival. Nor is there a requirement to make a positive profit in order for you to survive. Negative profits mean that you lose some of the money that you are endowed with.
- *After* you have chosen how much to produce, a ball will be drawn randomly from a bag, which will determine your selling price. You will sell your wheat at that price, which will determine your profit.
- You will first play 10 rounds of practice games. After the practice games, you will play 20 rounds of the real games. In the real games, your profits will affect your actual payoffs from the games.

- In this set of the game, you start from base payoff of $25. In a given round, your profit will be between -47.58 and 32.61. After the 20 actual rounds, we will randomly select a round. Your payoff from these games will be determined in the following way: $25 base payoff + a half of your profit in the randomly selected round. For example, if you have made a loss of 30 in the selected round, your final payoff will be $25 + (-$30 X 0.5) = $10. If you have made a profit of 28, your final payoff will be $25 + ($28 X 0.5) = $39.
- Your final payoff in this set of the games will range between $1.21 and $41.31.

Set II: Lottery Choice Game

- In this set of games, you will be presented a table of ten paired lotteries, A and B, from which you are asked to choose one that you prefer.
- Below is an example of the options that you will be given:

Option A	Option B
1/10 of $2.00, 9/10 of $1.60	1/10 of $3.85, 9/10 of $0.10

If you choose option A, there is a probability of 0.1 that you will be receiving $2.00, and a probability of 0.9 that you will be receiving $1.60. If you choose option B, there is a probability of 0.1 that you will be receiving $3.85 which is much bigger than $2.00 in option A. However, there is also a 0.9 probability that you will be receiving only $0.10.

- Stop once you have chosen the option B.
- Your payoff from this round of game will be determined in the following way: A random number will be drawn to determine the row number of one of your choices. Then, according to the probability that the row of the choice dictates, either option A or B will be drawn, which will determine your payoff.
- Your payoff from this round will range between $0.1 and $3.85.

4

8.3 Appendix III: Answer Sheet (English)

Answer Recording Sheet **ID#:**

Set I: Single-Commodity Production Game

- **Record your choices of output on the vouchers.**

Set II: Lottery Choice Game

	Option A	Option B	Your Choice (circle one)
1	1/10 of $2.00, 9/10 of $1.60	1/10 of $3.85, 9/10 of $0.10	A , B
2	2/10 of $2.00, 8/10 of $1.60	2/10 of $3.85, 8/10 of $0.10	A , B
3	3/10 of $2.00, 7/10 of $1.60	3/10 of $3.85, 7/10 of $0.10	A , B
4	4/10 of $2.00, 6/10 of $1.60	4/10 of $3.85, 6/10 of $0.10	A , B
5	5/10 of $2.00, 5/10 of $1.60	5/10 of $3.85, 5/10 of $0.10	A , B
6	6/10 of $2.00, 4/10 of $1.60	6/10 of $3.85, 4/10 of $0.10	A , B
7	7/10 of $2.00, 3/10 of $1.60	7/10 of $3.85, 3/10 of $0.10	A , B
8	8/10 of $2.00, 2/10 of $1.60	8/10 of $3.85, 2/10 of $0.10	A , B
9	9/10 of $2.00, 1/10 of $1.60	9/10 of $3.85, 1/10 of $0.10	A , B
10	10/10 of $2.00, 0/10 of $1.60	10/10 of $3.85, 0/10 of $0.10	A , B

Stop once you have chosen the option B.

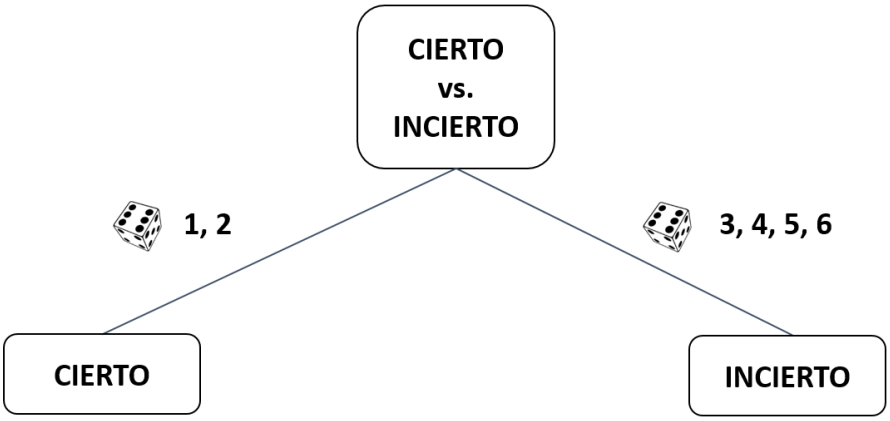
1

Demographics

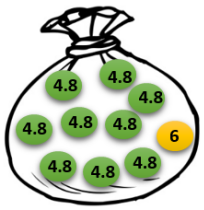
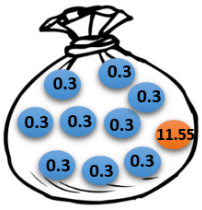
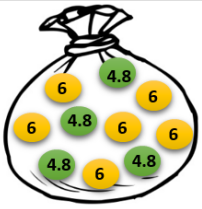
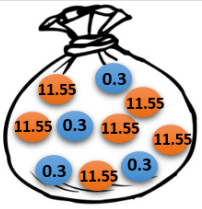
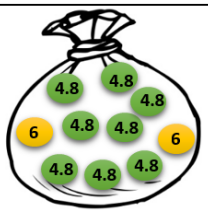
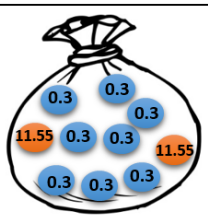
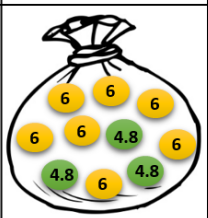
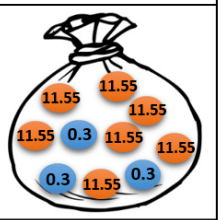
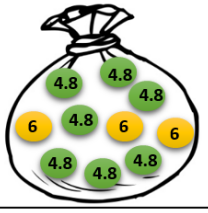
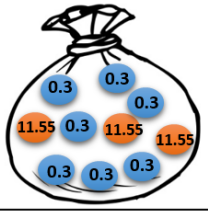
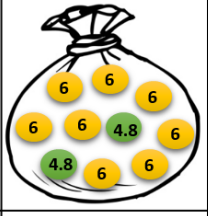
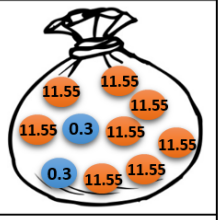
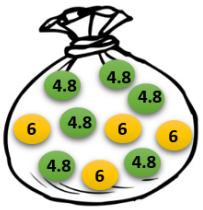
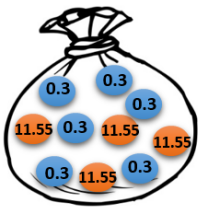
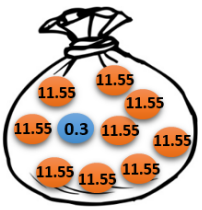
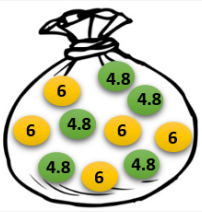
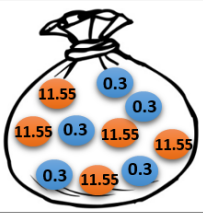
- Age:_____
- Sex: M / F
- Ethnicity/Race:
  (1) Hispanic or Latino
  (2) American Indian or Alaska Native
  (3) Asian
  (4) Black or African American
  (5) Native Hawaiian or Other Pacific Islander
  (6) White
- Nationality: _____

Thank you for your participation! ☺

8.4 Appendix IV: Randomization Chart (Spanish)



8.5 Appendix V: Graphical Holt-Laury List (Spanish)

	Opción A	Opción B		Opción A	Opción B
1			6		
6			7		
3			8		
4			9		
5			10