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Assessing small-scale raspberry producers' risk and ambiguity preferences: evidence from field-experiment data in rural Chile

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Abstract

Most researchers who analyze producers' preferences under uncertainty report that producers are averse towards risk and ambiguity scenarios. This aversion has an influence on producers' decision-making processes; hence the relevance of determining and analyzing these preferences as a key factor to design agricultural policies that help producers to cope with production uncertainty. In this study we elicit small-scale raspberry producers' preferences through field experiments in rural Maule (Chile). In addition, we identify producers' socioeconomic and farm characteristics that influence these preferences. Finally, we compare the two standard methods in the current literature to estimate producers' risk preferences from field experiments, and analyze if the estimation method influences these preferences.

Our results show an asymmetry in producers' risk preferences; producers are twice as sensitive to losses as to gains. Additionally, we find that producers get smaller lottery utilities in scenarios where ambiguity is present, which implies ambiguity aversion. We also show that the method used to estimate risk preferences can influence the results, with obvious implications for policy design.

Keywords: Risk Preferences, Ambiguity Preferences, Small-scale Producers, Raspberry Producers, Producers' Preferences Elicitation.

1 Introduction

Understanding risk and ambiguity preferences is important because these preferences influence producers' decision-making processes (Barham et al., 2014; Binswanger, 1980; Cardenas & Carpenter, 2013; Holt & Laury, 2002; Liu, 2012; Tanaka et al., 2010). In addition, small-scale producers face stiffer constraints to adapt their crops to uncertainty. Hence, researchers are increasingly conducting field experiments with small-scale producers, mostly in developing countries, to determine their risk and ambiguity preferences and to analyze the influence of these preferences on many aspects of farm decision-making, for instance: technology adoption (Barham et al., 2014; Liu, 2012), agricultural insurance demand (Elabed & Carter, 2015; McIntosh et al., 2015) and climate change adaptation (Alpizar et al., 2011).

Initially, researchers analyzed production uncertainty as composed of risk preferences alone. However, many researchers have found that producers behave differently when dealing with risk and ambiguity, and that risk and ambiguity correspondingly have different implications for producers' decision-making (Alpizar et al., 2011; Barham et al., 2014; Ross et al., 2010; Warnick et al., 2011). Hence, we consider uncertainty as being composed of two components: risk and ambiguity. Ihli & Musshoff (2013) show that uncertainty aversion can lead to sub-optimal decisions by producers.

Most of the studies that analyze producers' risk and ambiguity preferences focus on developing countries. However, in such countries it is uncommon to have access to data that allows to measure risk and ambiguity from pre-existing information. Consequently, researchers have developed experimental methods to elicit risk and ambiguity preferences from binary choice experiments under controlled conditions (Holt & Laury, 2002; Tanaka et al., 2010; Ward & Singh, 2015; Warnick et al., 2011). Although, the majority of empirical literature on risk and ambiguity preferences focuses on developing countries, the elicitation of these preferences is a field scarcely explored in Latin America.

Understanding risk and ambiguity preferences is a key ingredient in designing effective policies. For example, the Chilean government has a special interest in helping farmers cope with the uncertainty that arises from climate change and climate variability. According to Universidad de Chile (2006), central and southern areas of the country show a decreasing trend in rainfall since the 1970s. This increases the probability of droughts, and creates shocks that can have negative effects on agricultural production. These shocks especially affect small-scale producers, who usually face stiffer constraints to adapt their production systems (Handschuch et al., 2013; Morton, 2007). The Chilean government has implemented a National Forestry, Farming and Livestock Development Adaptation to Climate Change plan to help producers cope with this situation. One of the key components of this plan refers to producers' adoption of agricultural insurance and agricultural innovations such as improved varieties, drip irrigation, and other practices to cope with production uncertainty (Gobierno de Chile, 2013). However, as of today there are no studies that measure producers' risk and ambiguity preferences in Chile as an input into improving the design of such policies.

In this study we focus on small-scale raspberry producers in Chile. Raspberry production is attractive for small-scale producers, because of its low investment and mechanization requirements, and its labor intensity (Jara-Rojas et al., 2016; Toledo & Engler, 2008). Consequently, most of the raspberry production in Chile is in the hands of small-scale producers. Currently, more than twenty thousand households in Chile depend on raspberry production for at least part of their income (Domínguez, 2012). Due to soil and climate conditions raspberry production is concentrated in central regions of Chile. The Maule region alone accounts for more than 16 thousand small-scale Chilean raspberry producers (Domínguez, 2012; Jara-Rojas et al., 2016).

Our objectives are first to elicit small-scale raspberry producers' risk and ambiguity preferences using economic field experiments in rural areas of Maule region, and second to identify the socioeconomic and farm level determinants of these preferences. To elicit producers' risk and ambiguity preferences, we use the experimental procedure proposed by Tanaka et al. (2010) and Ward & Singh (2015). In addition, we use probit and OLS models to identify factors that influence producers' risk and ambiguity preferences respectively (Galarza & Carter, 2011; Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015). As a third objective, we analyze whether producers' risk preferences vary according to the estimation method. We do this by comparing the two standard methods that are used to analyze risk preferences from field experiments: the midpoint method (Liu, 2012; Nguyen, 2011; Tanaka et al., 2010; Ward & Singh, 2015) and the structural method (Andersen et al., 2014; Bocqueho et al., 2013; Harrison et al., 2010).

Our findings generate insights into producers' decision-making processes under uncertainty in three ways. First, we do not use results based on experiments with students, instead, we generate results using field experiments with actual producers. Second, we contribute to current literature by distinguishing between the possibly different determinants of producers' risk and ambiguity preferences. Third, we are not aware of other studies that elicit producers' risk and ambiguity preferences specifically in Chile, neither are we aware of other studies that analyze preferences conjointly in any other Latin American countries.

In Section 2 we review the current literature on raspberry production in Chile and on the elicitation of producers' risk and ambiguity preferences using experimental procedures. In Section 3 we describe our sample and data collection process, respectively. In section 4 we detail our structural specification, and we describe our results and concluding remarks in sections 5 and 6, respectively.

2 Raspberry production and producers' preferences for risk and ambiguity aversion in Chile

2.1 Chilean raspberry production and small-scale producers

During the 1980s Yugoslavia was the largest raspberry producer in the world. However, when the Yugoslav War started, raspberry production was interrupted. This created a shortage on international markets, and corresponding opportunities for producers in other countries. As a result, raspberry production in Chile increased from nearly nothing in 1980s to thirty thousand tons in 1990s (Domínguez, 2012). Following the cessation of hostilities, raspberry production in Yugoslavia began to recover in the early 2000s, ending the raspberry shortage on international markets. This reduced the profit of many large and medium Chilean raspberry producers, who then decided to switch their production towards more profitable crops, thus creating an opportunity for small-scale raspberry producers to expand (Domínguez, 2012; Jara-Rojas et al. 2016). The labor intensity and low investments that raspberry production requires make it attractive for small-scale producers (Toledo & Engler, 2008).

Today Chile is one of the largest raspberry producers and exporters worldwide. It has roughly 16·000 ha of raspberry and more than 21·100 producers, most of who are located in central regions of Chile. Maule region alone has more than 16·300 raspberry producers and 10·800 ha dedicated to this crop. Consequently, in the central regions of Chile raspberry production represents an important source of income for many small-scale producers (Domínguez, 2012; Jara-Rojas et al., 2016).

Producing raspberries is a risky business. High international price volatility, financial constraints, climate change and climate variability are some of the sources of uncertainty that small-scale raspberry producers must face (Challies & Murray, 2011). Consequently, understanding producers' risk and ambiguity preferences can assist policy makers in designing policies that help producers cope with uncertainty in their production systems (Bocqueho et al., 2013). Nevertheless, to date there are no studies that elicit risk and ambiguity preferences in Chile, and, none that elicit fruit producers' risk and ambiguity preferences in Latin America.

2.2 The influence of producers' risk and ambiguity preferences on their decision-making

Following Barham et al. (2014) and Klibanoff et al. (2005), we consider uncertainty as made up of two components: risk and ambiguity. Risk aversion occurs when decision-makers know the probability distribution associated with different possible outcomes and try to avoid risk even at the cost of a reduction in income. For example, producers who are risk averse will be reluctant to adopt improved technologies even if they know the probabilities of the possible outcomes during the adoption process; hence, they prefer to keep their current technology, even if that means reduced earnings (Ward & Singh, 2015).

Ambiguity aversion arises when producers are unsure about the probability distribution associated with different possible outcomes. For example, small-scale producers generally have incomplete information about the price and yield distributions of the various crops that they can plant. A producer who is ambiguity averse will be unwilling to change his/her current crop, even when others might offer more benefits (Warnick et al., 2011).

Even though policy-makers could have informed guesses about the nature of producers' risk and ambiguity preferences, to assume the effect of these preferences on producers decision-making processes can lead to misperceptions and inefficiencies in policy-making process (Johansson-Stenman, 2008). This is also stated by Barham et al. (2014) who report that different agricultural decisions have different degrees of uncertainty for producers. Accordingly, the effect and/or magnitude of producers' risk and ambiguity preferences can vary according to the decision that producers are facing. Hence, producers' risk preferences have different implications for different decisions: adoption of improved farm management practices (Wossen et al., 2015), improved varieties adoption (Liu, 2012; Ward & Singh, 2015) and agricultural insurances uptake (Elabed & Carter, 2015; McIntosh et al., 2015).

As a result, numerous authors have conducted research with experimental methods to study producers' risk preferences in developing countries (Alpizar et al., 2011; Barham et al., 2014; Bocqueho et al., 2013; Cardenas & Carpenter, 2013; Galarza & Carter, 2011; Harrison et al., 2010; Liu, 2012; Nguyen, 2011; Tanaka et al., 2010; Ward & Singh, 2015). Of these studies only Liu (2012) and Nguyen (2011) deal with small-scale producers; Alpizar et al. (2011), Warnick et al. (2011), Galarza & Carter (2011) and Cardenas & Carpenter (2013) work in Latin America. In addition, Toledo & Engler (2008) measure risk aversion in a setting close to ours; however they do not use elicitation methods to measure producers' risk preferences.

However, there is comparatively less research on producers' ambiguity preferences in developing countries (Alpizar et al., 2011; Cardenas & Carpenter, 2013; Ross et al., 2010; Takahashi, 2013; Ward & Singh, 2015; Warnick et al., 2011). Among these studies; Alpizar et al. (2011), Cardenas & Carpenter (2013), Ward & Singh (2015) and Warnick et al. (2011) distinguish between producers' risk and ambiguity preferences. These studies produce mixed results. For instance, Alpizar et al. (2011), Ross et al. (2010) and Warnick et al. (2011) report significant evidence about producers' ambiguity aversion on Costa Rica, Lao PDR and Peru, respectively. Yet Cardenas & Carpenter (2013), Takahashi (2013) and Ward & Singh (2015) do not find significant evidence of producers' ambiguity preferences in studies covering Colombia, Argentina, Venezuela, Peru, Uruguay and Costa Rica, Indonesia and India.

Most studies that analyze producers' risk and ambiguity preferences focus on the influence of these preferences on farm-related decisions such as technology adoption, agricultural insurance uptake, and crop diversification (Liu, 2012; Love et al., 2014; McIntosh et al., 2015; Nguyen, 2011; Tanaka et al., 2010; Ward & Singh, 2015). However, the factors that influence a producer's risk and ambiguity preferences have scarcely been explored in developing countries. The few exceptions include Elabed & Carter (2015), Galarza & Carter

(2011) and Harrison et al. (2010). In this paper we elicit risk and ambiguity preferences and we also study the socioeconomic and farm-level factors that explain variation in these preferences across individual smallholders.

Two standard methods have been used to analyze producers' risk preferences from field experiments: the midpoint method (Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015) and the structural method (Andersen et al., 2006; Bocqueho et al., 2013; Harrison et al., 2010). The structural method uses a maximum likelihood approach to create latent variables to estimate producers' risk preferences (Bocqueho et al., 2013; Harrison & Rutström, 2008). According to Harrison & Rutström (2008) and Andersen et al. (2010), the structural method is preferred because it has advantages for multi parameter estimation, such as risk preferences which parameters are estimated jointly.

The midpoint method is an analytical approach that uses a series of equations to calculate a producer's risk preferences (Harrison & Rutström, 2008). This method uses information from risk experiments around the producer's switching choice during risk experiment's series to jointly create producer's risk preferences' upper and lower bounds (Bocqueho et al., 2013; Liu, 2012).

According to Andersen et al. (2008), the structural method is a flexible way to estimate producers' risk preferences from field experiments. We agree with that statement, considering that this method uses maximum likelihood to maximize producers' risk preferences' parameters, while using first and second derivatives to achieve the maximization process and minimizing parameter's variance.

Even though that midpoint and structural methods are standard to estimate risk preferences from field experiments, as of today only Bocqueho et al. (2013) compare the results of producers' risk preferences by using both methods in a developed country context. Therefore, we contribute to current literature with empirical evidence about producers' risk preferences estimated by using both methods in an emerging economy.

3 Survey and experimental setting

3.1 Survey

The data were collected in a survey carried out from June to September 2015 in nine rural communes of Maule region: Molina, Romeral, Longaví, Parral, Retiro, Yerbas Buenas, Río Claro, Curicó and San Clemente. These communes are known in Maule for their raspberry production (Instituto de Desarrollo Agropecuario, 2007). One the most relevant actors that work with small-scale berry producers in Maule region is the National Institute for Agricultural Development (INDAP, official acronym in Spanish), a state department that focuses its work on small-scale producers in Chile. We selected households for our survey based on INDAP's 2011 national dataset of raspberry producers (Instituto de Desarrollo Agropecuario, 2011). From this dataset, we randomly selected 250 small-scale raspberry producers who live in rural Maule. We contacted these producers by phone to make appointments, and conducted field experiments and questionnaires. Of the 250 producers selected from INDAP's list, 148 were excluded because they no longer produce raspberries, their contact information was incorrect, or they were not willing to participate. Ultimately, we conduct our field experiments and questionnaire with 102 producers (Figure 1).

During the initial phone call, we informed producers that the session would last about ninety minutes, but we did not inform them about the experiment or the incentive for participating. As a result, a potential participants' decision to take part in the survey was not affected by his/her risk and ambiguity preferences, which reduces the likelihood of selection bias.

In addition to the experiment, we also interviewed producers according to a survey to collect information on their socioeconomic characteristics and the characteristics of their farm operations that could influence their risk and ambiguity preferences.

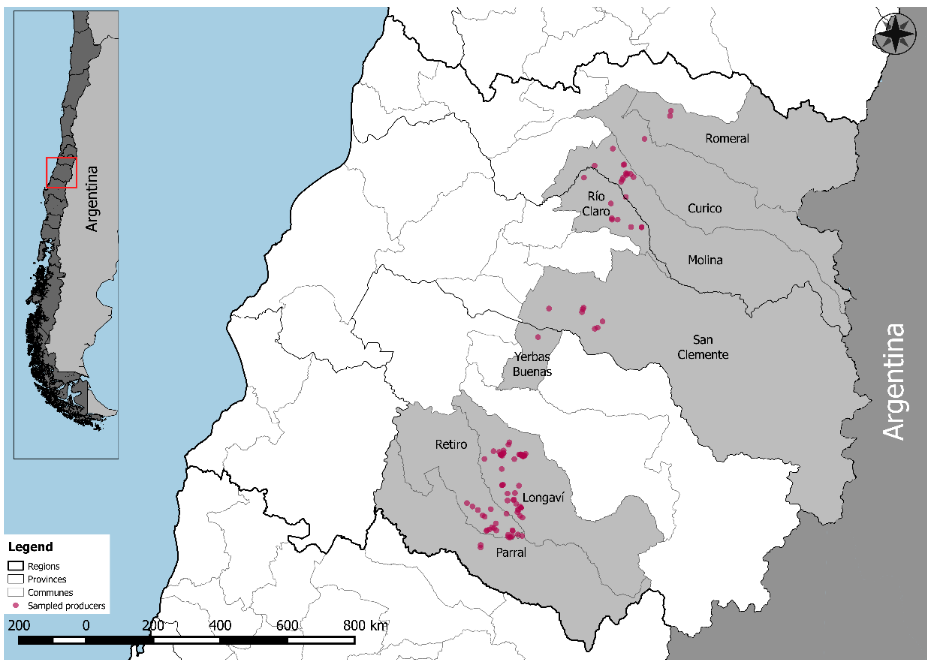

Figure 1. Location of sampled producers in rural Maule, Chile
Source: Authors' own calculations based on Sistema Integrado de Información Territorial (SIIT) (2014)

Table 1. Descriptive statistics

Variable description	Mean	Standard error
Producer's age	51.25	1.30
Household size	3.39	0.11
Years of education	7.96	0.32
Total raspberry area (ha)	0.50	0.05
Total farm size (ha)	3.60	0.63
Proportion of producers who have off-farm income	0.33	0.05
Proportion of producers with access to saving accounts	0.50	0.05
Proportion of producers with access to agricultural loans	0.54	0.05
Years working with raspberry	10.65	0.64
Proportion of producers who are members of farmers’ association	0.19	0.04
Monthly household expenditure (Chilean pesos)	226·657	10·613
Total observations	**102**	

Source: own calculations

Table 1 shows descriptive statistics of our sample. On average, producers are just over 51 years of age, their households are composed of three to four members, and the household head has eight years of education. The average total farm size is 3.6 hectares, of which 0.5 hectares are used to grow raspberries. In addition, fifty percent of the surveyed households have access to saving accounts, and 54 percent have access to agricultural loans. Also, producers have more than ten years of experience working with raspberries, and 19 percent of them are members of a farmers' association. Finally, one-third of the producers earn off-farm income, and their mean monthly household expenditure is 226·657 Chilean pesos (approximately € 325)[1].

3.2 Structure of the experimental session

We describe the data collection process in two sub-sections. The first sub-section describes the field experiments used to elicit producers' risk and ambiguity preferences, and the second sub-section describes the questionnaire that we used to collect information on producers' socioeconomic and farm characteristics.

To elicit producers' risk preferences, we followed Ward & Singh's (2015) modification of Tanaka et al.'s (2010) MPL experiment. This experiment has a well-defined structure, calibrated payouts and it is simple to use. We used another modification proposed by Ward and Singh to determine producers' ambiguity preference. By combining these modified experiments, we were able to maintain the same general structure and rules during the experimental sessions, which increased producers' comprehension and reduced errors and inconsistencies.

The experimental session was divided into risk and ambiguity experiments; during both experiments, producers faced a series of binary choices (rounds) to elicit their risk and ambiguity preferences. The ambiguity experiment consisted of two series, each of 11 rounds, and the risk experiment consisted of three series, two of 14 rounds and one of seven. In total, producers were presented with 57 rounds. Each round was composed of a safe lottery (lottery A) and a risk lottery (lottery B). Whenever lottery A was selected, producers won a certain amount of money; however, when lottery B was selected then producers faced two possible outcomes, winning and losing. Compared with the safe lottery A, the winning outcome in lottery B involved a larger payment, and the losing outcome involved a smaller payment.

Each producer's task during the experimental session was to decide which lottery he/she would choose for every one of the 57 rounds. To minimize errors during both experiments, we followed Tanaka et al. (2010) and Andersen et al. (2006) and asked producers to select from each series the round at which they would like to switch lotteries. However, we did not force them to switch; in this way, we assured that producers' answers capture their true preferences under risk and ambiguity scenarios.

During the experimental session we encountered four types of behavior: producers who never switched, whom we consider to be strongly risk averse; producers who switched at the beginning, whom we consider to be strong risk seekers; farmers who switched from one lottery to the other according to the expected value,

[1] When the fieldwork was conducted the exchange rate was just under 700 Chilean pesos per Euro.

whom we consider to be risk neutral; and producers who switched back and forth among lotteries, whom we consider to be inconsistent[2] (Bocqueho et al., 2013; Tanaka et al., 2010; Ward & Singh, 2015).

3.3 Experiment's incentive

To capture producers' true risk and ambiguity preferences, we provided participants with two monetary incentives. First, we gave an incentive at the beginning of the experiment. This incentive had two goals: to convince producers that they would earn money during this session, and to create an endowment effect in their minds (Liu, 2012; Tanaka et al., 2010). This endowment effect has crucial implications for producers' risk preferences in losses domain elicitation.

Second, immediately after we gave the first part of the incentive to producers, we explained that they would earn more money according to their decisions during the session. We clarified that one of the ensuing rounds would be selected randomly, and we that would pay more money according to their decision in that round. The goal of this incentive was to encourage them to consider all of their decision carefully. On average, producers earned roughly 14·000 Chilean pesos (roughly € 20) altogether.

To randomly select the round that determined the final pay-off, we used two black opaque bags. The first bag contained numbered chips that corresponded to each round of the experimental session. Producers selected one chip and the number selected determined the pay-off round. If a producer chose the safe lottery in this round, then he/she received the riskless amount of money declared in the series; if the producers chose the risky lottery in this round, then he/she was asked to draw from the second bag. This bag contained ten balls, some blue (winning) and some green (losing). The proportion of blue and green balls varied according to the probabilities stated in each series, and the color of the ball selected determined the amount of the final pay-off.

3.4 Ambiguity experiment

In both series of the ambiguity experiment, lottery A had a constant payment across all rounds. Similarly, the winning outcome in lottery B was also constant, but it involved a larger payment than lottery A, while the losing outcome in lottery B was smaller and decreased as the rounds progressed (Table 4). To integrate the ambiguity specification into the experiment, during the first series of this experiment we intentionally did not reveal probabilities of winning and losing outcomes in lottery B. Therefore, producers needed to decide whether and when to switch based on a comparison of lottery A with known information and probabilities, and lottery B with incomplete information.

One of the assumptions of this experiment is that producers subjectively assign probabilities to winning and losing outcomes in lottery B. Hence, to capture this information, after the first series we asked them to reveal

[2] One of the assumptions of risk experiments is that producers switch from lottery A to lottery B according to the lottery outcome. Lottery A's outcome remains constant in all rounds, while the outcome of lottery B increases monotonically from round to round. It is expected that producers will eventually switch to lottery B to earn a larger outcome, however we do not expect producers to switch back to lottery A to earn a smaller outcome. Hence, we consider producers who switch back and forth between lotteries to be inconsistent (Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015).

what they thought were the probabilities associated with the outcomes in lottery B. This is the only series in the experimental session in which we kept information from producers, and to avoid that their assessments be biased by the information that they received in other series, we began the experimental session with this series.

In the second series of this experiment, producers faced the same outcomes as in the first; however, this time we revealed the probabilities associated with winning and losing outcomes in lottery B. Since producers were provided with complete information in both lotteries, there was only risk and no ambiguity specification in this series.

3.5 Risk experiment

In the first two series of risk experiment, the outcome in lottery A was constant across all rounds. Similar to lottery A, the losing outcome in lottery B was also constant. However, in the risk experiment the winning outcome in lottery B increased as the rounds progressed (Table 5).

The third series of the risk experiment differed from the previous series in two ways. First, there was no certain outcome in lottery A, as both lotteries A and B involved winning and losing outcomes. Second, the losing outcome in both lotteries involved real losses (Table 6). However, these losses were designed so that given the initial incentive provided to all producers, no one could lose money overall. In addition, the endowment effect created with the first part of the incentive was necessary for this experiment to reveal producers' risk preferences in the loss domain. Producers realized that they could lose at least part of the initially provided incentive and, hence, had an incentive to reveal their true preferences.

4 Structural specification and experimental derivation of risk and ambiguity preferences

To address producers' risk and ambiguity preferences we estimate four parameters. First, the curvature of the prospect value function (σ) reflects how a producer behaves when confronted with risk in the gains domain. Second, the loss aversion parameter (λ) captures how a producer behaves when facing risk in the losses domain. Third, the probability weighing parameter (γ) characterizes whether producers disproportionately give more importance to low probability events when facing risk. Fourth, the augmented utility parameter (θ) dictates how a producer's utility that results from lotteries varies when he/she faces both risk and ambiguity scenarios. The interaction of the σ, λ and γ parameters reflects producers' risk preferences, and θ captures their ambiguity preferences (Harrison et al., 2010; Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015).

We follow Ward & Singh's (2015) method to assess producers' risk and ambiguity preferences, but deviate from their study in three ways. First, Ward & Singh only use the midpoint estimation method to assess producers' risk and ambiguity preferences, whereas we also use the structural method to assess their risk preferences (Bocqueho et al., 2013; Harrison et al., 2010). Second, Ward and Singh (2015) calculate two versions of ambiguity preferences: naïve and subjective. In naïve estimation, the producers' subjective probabilities are assumed to be $\hat{p} = 1 - \hat{p} = 0.5$, during the first series of the ambiguity experiment. In subjective estimation subjective probabilities provided by producers following the first series of the experimental session are used. We consider that the probability assumption underlying the naïve estimation is unrealistic and consequently we only carry out the subjective estimation. Third, Ward and Singh (2015) analyze the influence of producers' risk and ambiguity preferences on the adoption of improved varieties. We focus instead on analyzing the socioeconomic and farm factors that influence a producer's ambiguity and risk preference, and not on the effect of these preferences on a specific decision.

4.1 Producers' risk preferences estimation with the structural method

During risk experiment, producers face scenarios with two possible outcomes, x and y in the gains and losses domains. Hence, the CPT first establishes two coefficients to differentiate among these domains (Bocqueho et al., 2013; Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015):

$$v(x) = \begin{cases} x^{\sigma} & if\ x > 0 \\ -\lambda(-x)^{\sigma} & if\ x < 0 \end{cases} \tag{1}$$

In (1) σ represents the curvature of the prospect value function in the gains domain. This preference should be greater than zero. $\sigma < 0.5$ denotes a strong concavity in the curvature of the prospect value function, which correlates with a strong risk aversion; $0.5 < \sigma < 0.9$ implies moderate risk aversion; $\sigma = 1$ implies risk neutrality; and $\sigma > 1$ implies risk seeking behavior.

Furthermore, λ represents producers' sensitivity to losses. If $\lambda > 1$, then producers are more sensitive to losses than gains; if $\lambda < 1$, then they are less sensitive to losses; and $\lambda = 1$ suggests that producers are indifferent.

We follow Tanaka et al. (2010) and calculate the decision weights based on cumulative probabilities, this equation is written as:

$$u(x,y,p) = \begin{cases} v(y) + \omega(p) \cdot (v(x) - v(y)) & if\ x \geq y \geq 0\ or\ x \leq y \leq 0 \\ \omega(p) \cdot v(x) + \omega(1-p) \cdot v(y) & if\ x < 0 < y \end{cases} \tag{2}$$

where $u(x,y,p)$ represents producers' lottery utility with outcomes x and y, and probabilities p and $1-p$, respectively, and $\omega(\cdot)$ is a probability weighting function that measures whether a producer distorts probabilities of unlikely events. To be consistent with recent literature, we follow Tanaka et al. (2010), Liu (2012), Bocqueho et al. (2013) and Prelec's (1998) to define this function as:

$$\omega(p) = \exp[-(-\ln p)^{\gamma}] \tag{3}$$

where γ captures whether producers distort the probabilities of events when facing risk situations. If $\gamma < 1$, this function has an inverse s-shape form, which means that producers over-weigh low probability outcomes and under-weigh high probability results. When $\gamma = 1$, there is no probability distortion and the function is a straight line. When $\gamma > 1$ the function takes a s-shape form and producers tend to under-weigh extreme events (Nguyen, 2011; Tanaka et al., 2010).

We consider Δ_{RP} to be the producers' utility difference between both lotteries. We use Δ_{RP} as an input variable in the following likelihood function, which is conditional to the structural specification:

$$\ln L^{RP}(\delta, X;\ \sigma, \gamma, \lambda) = \sum_{k} \left[ln\Phi(\Delta_{RP}) \times I\left(\delta_j = A\right) + \ln(1 - \Phi(\Delta_{RP})) \times I\left(\delta_j = B\right) \right] \qquad (4)$$

In equation (4), Φ represents the cumulative distribution function of the standard normal distribution and the δ_j are the producers' lottery choices. The maximum likelihood function for $(\sigma, \gamma, \lambda)$ is:

$$\left(\hat{\sigma}, \hat{\gamma}, \hat{\lambda}\right) = \arg\max \ln L^{RP}(\delta, X;\ \sigma, \gamma, \lambda) \qquad (5)$$

To calculate $\left(\hat{\sigma}, \hat{\gamma}, \hat{\lambda}\right)$, we implement the maximum likelihood probit method[3] in STATA, following structural method by Harrison (2008) and Bocqueho et al. (2013). This method allows us to estimate producers risk preferences by using all producers' decisions during the experiment. Since, decisions from the same producer could be correlated, we cluster the standard errors in our estimation (Andersen et al., 2010; Bocqueho et al., 2013; Harrison, 2008)[4].

4.2 Producers' risk preferences estimation with the midpoint method

We also estimate γ and σ jointly using the midpoint method (Tanaka et al., 2010; Liu, 2012). This method applies equations (1) through (3) to information generated by the switching choices between lotteries A and B of the risk experiment. Applying these equations produces a set of inequalities for each series; solving for γ and σ in these inequalities, we estimate parameters' upper and lower bounds.

Since there are many values of γ and σ that satisfy these inequalities, we use the combination of these parameters that maximizes producers' expected utility from both lotteries. For example, consider, a producer who in the risk section switches at choice five in series one and at choice six in series two; in this case we must solve the following inequalities:

$$Series\ 1 \begin{cases} 0^{\sigma} + \exp[-(-\ln 1)^{\gamma}] * (1200^{\sigma} - 0^{\sigma}) > 600^{\sigma} + \exp[-(-\ln 0.1)^{\gamma}] * (4900^{\sigma} - 600^{\sigma}) & if\ \delta_j = A \\ 0^{\sigma} + \exp[-(-\ln 1)^{\gamma}] * (1200^{\sigma} - 0^{\sigma}) < 600^{\sigma} + \exp[-(-\ln 0.1)^{\gamma}] * (5650^{\sigma} - 600^{\sigma}) & if\ \delta_j = B \end{cases}$$

$$Series\ 2 \begin{cases} 0^{\sigma} + \exp[-(-\ln 1)^{\gamma}] * (4000^{\sigma} - 0^{\sigma}) > 500^{\sigma} + \exp[-(-\ln 0.7)^{\gamma}] * (6900^{\sigma} - 500^{\sigma}) & if\ \delta_k = A \\ 0^{\sigma} + \exp[-(-\ln 1)^{\gamma}] * (4000^{\sigma} - 0^{\sigma}) < 500^{\sigma} + \exp[-(-\ln 0.7)^{\gamma}] * (7300^{\sigma} - 500^{\sigma}) & if\ \delta_k = B \end{cases}$$

In these inequalities, γ and σ are the arguments that we jointly maximize to quantify the producer's risk preferences. δ_j and δ_k represent a producers' lottery choice regarding the switching round in series one and two of the risk experiment, respectively. In this example, the values for γ and σ that maximize utility are 1 and 0.91 for series one, and 1 and 0.77 for series two; hence, the mean values are 1 and 0.84 for σ and γ, respectively.

We calculate λ from the third series of the risk section. Since we know producers' switching choice, and equations (1) and (2), solving for λ produces the loss aversion parameter equation (6) (Liu, 2012; Tanaka et

[3] To be consistent with recent literature, we used a probit model for our calculations. The results of a logit estimation (available from the authors) are similar.

[4] Since during the risk experiment, each producer faces a total of 35 decisions to make (rounds) and we cluster by producers. Altogether we have a total of 3255 observations in 93 clusters.

al., 2010; Ward & Singh, 2015). Since the probability for every outcome in lottery B is the same ($p = 1 - p = 0.5$), γ does not play a role in this estimation and is dropped from λ parameter calculation.

$$\lambda_j(\sigma) = \frac{x_{j,A}^{\sigma} - x_{j,B}^{\sigma}}{(-y_{j,A})^{\sigma} - (-y_{j,B})^{\sigma}} \tag{6}$$

4.3 *Producers' ambiguity preference estimation*

Following Ward & Singh (2015), we also use the midpoint method to determine producers' ambiguity preference. Therefore, we assume that a producer's utilities at the switching choices of both lotteries are equal; in other words:

$$U(x_A) = [U(x_{j,B}, y_{j,B}; \hat{p}, 1 - \hat{p}; \gamma, \sigma)]^{\theta} \tag{7}$$

where x and y are winning and losing outcomes, respectively, and j represents switching choice during series one, in which we did not inform producers about the probabilities of outcomes in lottery B. Hence, to reveal a producer's subjective probability after the first series we asked him/her what he/she thinks are the probabilities associated with winning ($\hat{p}$) and losing ($1 - \hat{p}$) in lottery B, and we use these probabilities in equation (7). Consequently, θ captures a producer's ambiguity preference based on his/her choice of an ambiguity lottery with incomplete information over a safe lottery with complete information. λ only arises when analyzing risk preferences in the loss domain; since we analyze producers' ambiguity preference on gains domain, we do not calculate a loss aversion parameter.

To calculate producers' utility based on the second series of the ambiguity experiment, we also use equation (7). Since we reveal the probabilities associated with winning and losing outcomes to the producers, θ does not play a role in this series. Furthermore, since outcomes for lotteries A and B are equal in both series, we can compare a producer's utility in both series at switching choices j and k for the first and second series, respectively. Then, solving for θ we find the equation that captures the producer's ambiguity preference:

$$\theta = \frac{\ln U(x_{k,B}, y_{k,B}; p, 1 - p; \gamma, \sigma)}{\ln U(x_{j,B}, y_{j,B}; \hat{p}, 1 - \hat{p}; \gamma, \sigma)} \tag{8}$$

$\theta > 1$ implies that the utility that results from the lottery is larger when ambiguity is absent, i.e. that the producer is ambiguity averse. If $\theta = 1$ then the producer derives the same utility from both series, i.e. he/she is ambiguity neutral. If $\theta < 1$ then the utility from the lottery is larger when ambiguity is present, i.e. the producer is an ambiguity seeker.

To identify the factors that influence producers' risk and ambiguity preferences, we follow Harrison & Rutström (2008) and Ward & Singh (2015) and conduct probit and OLS models to regress these preferences on a set of producers' socioeconomic and farm characteristics. According to the current literature, we expect that producer's assets decrease producer's risk aversion. Hence, we include available land to produce and off-farm income as covariates (Liu, 2012; Tanaka et al., 2010; Ward & Singh, 2015). Also, we expect that producers who are more risk averse tend to look for risk-sharing institutions, such as farmers' associations (Mobarak & Rosenzweig, 2013). In addition, we include other producer's characteristics that could decrease producers' risk and ambiguity aversion, such as years of education, access to agricultural loans, producer's experience working with raspberry, and household expenditure as a proxy for producers' household income (Cardenas & Carpenter, 2013; Warnick et al., 2011). Furthermore, we include producer's gender to identify if there are differences of producers' risk and ambiguity preferences between male and female producers (Ward & Singh, 2015). Finally, we include additional characteristics that we expect them to increase producers' risk and ambiguity aversion, such as the producer's age and household size (Alpizar et al., 2011; Harrison et al., 2010; Ross et al., 2010; Warnick et al., 2011). Although many studies find no evidence that household expenditure, household size, and available land influence producers' risk and ambiguity preferences, we believe that they might have an influence in the Chilean context (Liu, 2012; Ward & Singh, 2015; Warnick et al., 2011).

5 Results

Following Hirschauer et al. (2014), inconsistent producers can bias the mean and variance of producers' risk and ambiguity preferences estimates. In our data, nine producers show inconsistent behavior and are excluded from the analysis.

In the following we first present the results of the estimation of producers' risk preferences. Then we show how these estimates differ depending on whether they are produced using the midpoint or the structural method. Later we present the results for the regression of producers' risk preferences on a set of producers' characteristics. Finally, we present the results for producers' ambiguity preference and the regression of producers' ambiguity preference on producer specific socioeconomic and farm characteristics.

5.1 Producers' risk preferences estimation method comparison

Our estimates for producers' risk preferences parameters (γ, λ and σ) are shown in Table 2. We find with the structural method that producers' risk preferences are significantly different from zero ($p < 0.001$), and that $\lambda > 1$ and $\sigma < 1$, both at 99 percent significance level ($p < 0.001$). This implies that producers are risk and loss averse.

We find that $\gamma = 0.952$, with a 95 percent confidence interval of 0.791 – 1.111. Since this estimate is not different from one ($p = 0.56$), we conclude that on average, producers do not distort the probabilities of unlikely extreme events. This behavior is consistent with other theories in the literature that assume linear probability weighing among producers (Galarza, 2009; Harrison et al., 2010)[5]. Regarding loss aversion, we find that $\lambda = 2.06$, with a 95 percent confidence interval of 1.607 – 2.517. This suggests that producers are roughly twice as sensitive to losses as they are to gains. This result is consistent with those of Liu (2012) ($\lambda = 3.47$) and Nguyen (2011) ($\lambda = 3.255$). We also find that $\sigma = 0.214$, with a 95 percent confidence interval of 0.199 – 0.228. This points to a strong risk aversion among producers (Andersen et al., 2010), and is similar to findings by Harrison et al. (2010) ($\sigma = 0.464$), Tanaka et al. (2010) ($\sigma = 0.59$) and Liu (2012) ($\sigma = 0.48$).

Table 2. Comparison of producers' risk preferences estimates

[5] Expected Utility Theory (EUT) is one of the most prominent theories used to address producers' risk preferences, and it assumes linear probability weighing among producers (Bocqueho et al., 2013; Harrison & Rutström, 2008; Tanaka et al., 2010).

	Structural method					Midpoint method				
	Coefficient	Std. Err.	95 percent confidence interval		$\beta_0 = 1$	Coefficient	Std. Err.	95 percent confidence interval		$\beta_0 = 1$
γ	0.952***	(0.082)	0.791	1.111	0.56	0.849***	(0.03)	0.787	0.910	0.00
λ	2.062***	(0.232)	1.607	2.517	0.00	3.543***	(0.28)	2.986	4.100	0.00
σ	0.214***	(0.007)	0.199	0.228	0.00	0.659***	(0.04)	0.583	0.734	0.00
θ						1.497***	(0.24)	1.020	1.973	0.04

Source: own calculations; Robust standard errors in parentheses;
*** p<0.01, ** p<0.05, * p<0.1

Furthermore, like Bocqueho et al. (2013) we find that producers' risk preferences estimates from both methods are similar. However, there are three important differences. First, that the estimate of σ from the structural method ($\sigma = 0.214$) is lower than that from the midpoint method ($\sigma = 0.659$). Hence, while our result for σ with the structural method suggests strong risk aversion, our result with the midpoint method suggests only moderate risk aversion. Second, λ increases from 2.062 with the structural method to 3.543 with the midpoint method. Hence, according to the midpoint method producers are on average three and a half times more sensitive to losses as they are to gains. Further, both changes on σ and λ increase the asymmetry between producers' risk preferences in gains and loses domains.

Third, the estimate of γ is similar for both estimation methods. However, according to the results of the structural method γ does not differ from one ($p = 0.56$), while with the midpoint method it is statistically smaller than one ($p < 0.01$). Hence, the structural estimate indicates that producers do not disproportionately distort the probabilities of unlikely events but the midpoint method estimate indicates that they over-weigh unlikely events (Bocqueho et al., 2013; Liu, 2012; Ward & Singh, 2015). Our estimate of γ with the midpoint method is similar to estimates by Liu (2012), Tanaka et al. (2010) and Ward & Singh (2015), who find that $\gamma = 0.69$, 0.74 and 0.736, respectively.

5.2 Producers' risk preferences determinants

In Table 3 we present the results of the probit and OLS regressions estimations of producers' risk and ambiguity preferences on their socioeconomic and farm characteristics respectively.

First, we find that γ increases with producers' age, education and available land to produce. Hence, older, more educated producers who farm more land are more likely to under-weigh unlikely events. In addition, producers who are members of a farmers' association and have larger household expenditures are more likely to over-weigh unlikely events. These results are similar to those of Galarza (2009) who finds that education has a significant influence on the size of the probability weighing parameter. We are not aware of any other studies that analyze the influence of membership in a farmers' association on risk preferences, but one possible explanation is that producers who over-weigh unlikely events consider farmers' associations as an informal means of risk sharing. Moreover, we are not aware of previous studies that find significant effects of household expenditure, household size, available land to produce, and producer's age on γ.

Second, as expected we find that producers' available land correlates with less loss aversion. In addition, λ is positively correlated with producer's age. However, the size of this effect is small. These results are similar to those of Liu (2012) who also reports that available land correlates with less loss aversion among producers, and Tanaka et al. (2010) who also show that producer's age is correlated with λ.

Third, our results show that producers' age and agricultural loans are associated with stronger risk aversion σ. Also, producers with larger household expenditure are less risk averse. Our results for this parameter are similar to Harrison et al. (2010) and Alpizar et al. (2011), who find that σ increases with age, and to Ward & Singh (2015), who report similar effects for expenditure.

Table 3. Regression estimates of producers' risk and ambiguity preferences on their socioeconomic and farm characteristics

	Variable description	Coefficient		Std. Err.
Producer's risk preferences				
γ	Constant	0.554		(0.692)
	Producer's age	0.021	*	(0.012)
	Female	-0.129		(0.148)
	Household size	-0.091		(0.103)
	Agricultural loans (1 = yes)	0.331		(0.341)
	Years studied	0.056	*	(0.031)
	Total available land	0.024	**	(0.010)
	Farmers' association member	-0.359	**	(0.177)
	Off farm income	0.013		(0.243)
	Monthly household expenditure (CLP 100·000)	-0.302	**	(0.149)
λ	Constant	0.884		(2.985)
	Producer's age	0.059	*	(0.032)
	Female	-0.560		(0.672)
	Household size	-0.135		(0.336)
	Agricultural loans (1 = yes)	-0.470		(1.207)
	Years studied	0.091		(0.161)
	Total available land	-0.125	***	(0.040)
	Farmers' association member	1.887		(1.209)
	Off farm income	-0.971		(0.740)
	Monthly household expenditure (CLP 100·000)	-0.309		(0.389)

[Continuation from Table 3]

	Variable description	Coefficient		Std. Err.
σ	Constant	0.178	*	(0.102)
	Producer's age	-0.002	*	(0.001)
	Female	-0.012		(0.023)
	Household size	0.013		(0.012)
	Agricultural loans (1 = yes)	-0.060	*	(0.032)
	Years studied	0.008		(0.007)
	Total available land	0.002		(0.001)
	Farmers' association member	-0.028		(0.031)
	Off farm income	-0.045		(0.038)
	Monthly household expenditure (CLP 100·000)	0.029	***	(0.010)
	Model p-value	0.002		
Producer's ambiguity preferences				
θ	Constant	0.096		(1.531)
	Age	-0.016		(0.019)
	Female	-1.130	*	(0.560)
	Household size	0.373	*	(0.218)
	Agricultural loans (1 = yes)	-0.966		(0.614)
	Total land available	-0.052		(0.043)
	Farmers' association member	-0.773		(0.627)
	Monthly household expenditure (CLP 100·000)	0.480	**	(0.237)
	Years working with raspberry	0.099	**	(0.042)
	Model p-value	0.080		
	r^2	0.068		

Source: own calculations; Robust standard errors in parentheses;
*** p<0.01, ** p<0.05, * p<0.1

5.3 *Producers' ambiguity preferences*

Our estimate of θ is 1.497, with a 95 percent confidence interval of 1.02 – 1.97 (Table 2). Since θ is significantly larger than one ($p = 0.041$), producers are, on average, ambiguity averse. This confirms findings by Alpizar et al. (2011) and Warnick et al. (2011), who report ambiguity aversion among small-scale producers in Costa Rica and Peru, respectively.

In Table 3 we report the results of regressing θ on a set of producers' socioeconomic and farm characteristics. Our results show that on average female producers are less ambiguity averse than male producers. Contrary to our expectations, household expenditure and years of experience working with raspberry are positively correlated with ambiguity aversion, as is household size. Cardenas & Carpenter (2013) also find a significant effect of gender on ambiguity preferences, however they report the opposite effect. This might be due to the fact that Cardenas & Carpenter study urban individuals from the capital cities of six countries in Latin America, while we study small producers in rural Chile.

In addition, we find that producers from larger households are more ambiguity averse. Warnick et al. (2011) also find a significant effect for household size on producers' ambiguity preference. Cardenas & Carpenter (2013) analyze the effect of producers' income, and Warnick et al. (2011) consider the influence of producers' experience on their ambiguity preference; however they do not find that these variables have significant effects. Furthermore, their studies are carried out in developed countries. To the best of our knowledge we are the first to analyze factors that influence ambiguity aversion in a developing country.

6 Conclusions

Our research contributes to the understanding of small raspberry producers' decision-making process by analyzing their risk and ambiguity preferences in rural Maule. We highlight three main findings. First, producers are strongly risk averse, and there is an asymmetry between the gains and losses domains, implying that on average producers do not behave in the same way for rewards and for penalizations. Producers put more effort into avoiding losses than into realizing gains (Bocqueho et al., 2013). In addition, we find that producers derive less utility from the experiments in which ambiguity is present, which implies that producers are on average ambiguity averse.

Second, our results show that the midpoint and structural methods produce different estimates of producers' risk preferences. The results from the midpoint method suggest that producers are less risk averse, and that the asymmetry between risk aversion in gains and losses domains is larger, than the results from the structural method. These different estimates have obvious connotations for agricultural policies and strategies design.

Third, we find that many producers' socioeconomic and farm characteristics are correlated with their risk and ambiguity preferences. According to our estimates, age, membership in a farmers' association membership, and current agricultural loans are positively correlated with a producer's risk and loss aversion. Years of education, total available land, and monthly household expenditure are negatively correlated with risk and loss aversion. We also find that male producers, household size, monthly household expenditure, and years of experience working with raspberry are positively correlated with ambiguity aversion.

Possible venues for future research are to apply different methods to measure producers' risk and ambiguity preferences, such as Harrison et al.'s (2010) mixture method to estimate risk preferences, and Cardenas & Carpenter's (2013) method to estimate ambiguity preference. Applying Tanaka et al.'s (2010) method for measuring time preferences could generate further insights into producers' behavior under uncertainty. Ultimately, research such as this can help public and private stakeholders design and improve policies and products that help smallholders in Chile deal with risk and uncertainty.

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Appendix

Table 4. Payoff schedule for ambiguity experiment (in Chilean pesos)

Round	**Lottery A**	**Lottery B**[+]		**Expected payoff difference**[*]
Series 1 and 2	*Probability = 1*	*Probability = 0.5*[+]	*Probability = 0.5*[+]	
1	2200	4400	2200	-1100
2	2200	4400	1800	-900
3	2200	4400	1400	-700
4	2200	4400	1100	-550
5	2200	4400	850	-425
6	2200	4400	750	-375
7	2200	4400	650	-325
8	2200	4400	550	-275
9	2200	4400	400	-200
10	2200	4400	200	-100
11	2200	4400	0	0

Source: own calculations

* Expected payoff difference (expected utility of lottery A – expected utility of lottery B) is not shown to producers.

+ The producers were not informed about these probabilities during the first series of the ambiguity section.

Table 5. Payoff schedule for the first two series of risk experiment (in Chilean pesos)

Round	**Lottery A**	**Lottery B**		**Expected payoff difference***
Series 1	*Probability = 1*	*Probability = 0.1*	*Probability = 0.9*	
1	1200	3100	600	350
2	1200	3400	600	320
3	1200	3850	600	275
4	1200	4300	600	230
5	1200	4900	600	170
6	1200	5650	600	95
7	1200	6700	600	-10
8	1200	7600	600	-100
9	1200	8650	600	-205
10	1200	10200	600	-360
11	1200	12500	600	-590
12	1200	16000	600	-940
13	1200	21750	600	-1515
14	1200	33600	600	-2700
Series 2	*Probability = 1*	*Probability = 0.7*	*Probability = 0.3*	
1	4000	5600	500	-70
2	4000	5700	500	-140
3	4000	6000	500	-350
4	4000	6200	500	-490
5	4000	6500	500	-700
6	4000	6900	500	-980
7	4000	7300	500	-1260
8	4000	7700	500	-1540
9	4000	8200	500	-1890
10	4000	8700	500	-2240
11	4000	9500	500	-2800
12	4000	10500	500	-3500
13	4000	11900	500	-4480
14	4000	13700	500	-5740

Source: Own calculations

* Expected payoff difference (expected utility of lottery A – expected utility of lottery B) is not shown to producers.

Table 6. Payoff schedule for third series of risk experiment (in Chilean pesos)

Round	**Lottery A**		**Lottery B**		**Expected payoff difference***
	Probability = 0.5	*Probability = 0.5*	*Probability = 0.5*	*Probability = 0.5*	
1	10000	- 2000	12000	- 8500	2250
2	2000	- 2000	12000	- 8500	-1750
3	500	- 2000	12000	- 8500	-2500
4	500	- 4000	12000	- 6800	-4350
5	500	- 4000	12000	- 6800	-4350
6	500	- 4000	12000	- 5900	-4800
7	500	- 4000	12000	- 4650	-5425

Source: Own calculations

* Expected payoff difference (expected utility of lottery A – expected utility of lottery B) is not shown to the producers.

Diskussionspapiere
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2000		
0001	Brandes, W.	Über Selbstorganisation in Planspielen: ein Erfahrungsbericht, 2000
0002	von Cramon-Taubadel, S. & J. Meyer	Asymmetric Price Transmission: Factor Artefact?, 2000
2001		
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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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