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Using Insights from Prospect Theory to Enhance Sustainable Decision Making by Agribusinesses in Argentina

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Received: 30 June 2018; Accepted: 23 July 2018; Published: 1 August 2018

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Abstract: Farm production often involves family-owned agribusinesses where decisions are made by households or individuals, not corporate managers. As these decisions have important economic, environmental, and social implications, decision-making processes must be understood to foster sustainable agricultural production. Decision experiments, involving lotteries, targeting farmers in the Argentine Pampas were used to estimate prospect theory (PT) parameters. Results suggest that decisions under risk are better represented by prospect theory than by expected utility (EU) theory: Decision makers treat gains and losses differently and use subjective probabilities of outcomes; they are quite loss averse and are more likely to overweigh probabilities of infrequent events, such as large droughts or floods. Statistical testing revealed heterogeneity in the risk tied to land tenure (land owners vs. renters) and agribusiness roles (farmers vs. technical advisors). Perceptions of risk, probability, and outcomes played a large role in the sustainability of production. Due to a strong desire to avoid losses, decision makers have a greater short term focus: Immediate economic outcomes are more salient, and environmental and social investments are framed as costs rather than long-term gains. This research can help design policies, programs, and tools that assist agribusinesses in managing better contradictions across the triple bottom line to ensure greater sustainability.

Keywords: risk preferences; prospect theory; land tenure; agribusiness decision making; sustainable agriculture

1. Introduction

Agribusinesses can play a critical role as food providers, rather than just act as profit maximizers, particularly in Argentina where these entities are typically small to medium sized organizations that are household- or family-owned, often with social ties within the local community. The decision processes of these agribusinesses involve important and unavoidable tradeoffs between different sustainability dimensions [1]. On the one hand, decision-makers seek to maximize profits and to ensure their immediate survival by preventing a loss. On the other hand, their very existence is linked to maintaining the long-term productivity of the land and employees, who have the knowledge and experience to help maximize output from each farm plot [1]. Therefore, agribusinesses need to balance the three pillars of sustainability: Profit, people, and the planet.

Food production, however, occurs in a context of increasing climate variability in which extreme weather events, like droughts, floods, and heat/cold waves, are expected to become more frequent, intense, or of a longer duration [2–6]. In the U.S., farmers have noticed an increase in extreme weather [7], and a similar intensification of extremes is emerging in the observed climate records across many parts of the world [8,9]. As agribusinesses face more frequent and extreme weather events due to climate change, achieving sustainability will become even more challenging. Balance across the three pillars will require that farmers adapt to climate change by changing their behavior and optimizing tradeoffs among and within the three pillars to meet market demand for specific commodities and products, while also ensuring their own long-term survival. It will also require that agricultural policies, programs, and decision tools consider how and why agribusinesses make management decisions and tradeoffs across the three pillars [1].

1.1. The Argentine Pampas

In this article, we study agribusiness decisions under risk in the Argentine Pampas, one of the most fertile agricultural regions of the world [10]. Specifically, we seek to understand how the risk preferences of agribusiness decision makers influence production choices. Argentina is a major contributor to global food security: It already produces amounts of grain that are sufficient to feed at least 200 million people, five times its current population, and has substantial potential to increase production even more [11]. Argentina is the leading world exporter of soybean oil and meal, and the third largest exporter of soybeans as beans.

Climate fluctuations, technological innovations, and global and local economic and social contexts have influenced agriculture in the Pampas over the last few decades [12]. The growing global demand for grains, local changes in the Argentine economy, and simplification of agronomical management [13] has enhanced the relative profitability of agriculture in Argentina. As a result, cropping related activities conducted by agribusinesses dominate, displacing pastures and native grasslands [14,15]. A most striking pattern has been the increasing dominance of soybeans. Despite the large income provided by soybean exports (≈1/3 of the value of all Argentine exports in 2016 involved soy oil, meal, or beans), there are growing concerns about the sustainability of "soybean monoculture" [16–24].

High land prices in the Pampas, together with the virtual inexistence of credit, have made growth via the purchase of land economically prohibitive. Instead, agribusinesses increase the size of their operations by renting additional land, a mechanism that involves much more affordable capital outlays. Owners of smaller extensions that are economically unviable [25] increasingly rent out their land to agribusinesses that both own and rent land, or to new firms entering the sector [26]. Consequently, land tenure patterns have changed rapidly: Recent estimates find approximately 60% of the land currently farmed by agribusinesses in the Pampas is rented [27]. Estimates place the size of the annual land rental market in the Pampas at over US$4 billion [28]. Typical leases for the land are annual and are, thus, characterized by frequent turnover. These short-term (annual) lease contracts induce maximization of short-term profits and discourage multiannual investments to preserve soil quality [29–31].

Argentine agriculture is not a subsidized sector: Agribusinesses take on the risks inherent in commodity markets; their economic incentive is the potential profit based on the actual crop price [32]. This risk manifests more strongly on land that is rented, as the rental payment is an upfront cost [28]. Additionally, the shift to export crops has introduced greater unpredictability due to environmental and social consequences from recent structural changes. Unlike pastures, which are multi-year investments present on the land year-round, agricultural crops are annual choices that may remain for any length of time between four to eight months. When land is fallow, it collects water through rainfall, but does not lose nearly as much through evapotranspiration that occurs when plants are in the ground. Thus, in many parts of the Pampas, the depth of the water table has shifted upwards by an estimated two meters over the course of the last twenty years [33], increasing the probability of inundation from severe rainfall. Floods and droughts have varying social and economic implications. Floods cause greater disruption of social life and capital, while droughts lead to greater economic hardship.

Similarly, social relationships have also been altered by the recent structural changes, raising issues of local learning, social capital, and cohesion [34]. Agribusiness decision makers who own the land may view the costs associated with maintaining long-term productivity of the land, building social capital, and encouraging local participation as low-risk investments, whereas those renting the land may be less willing to invest in such longer-term investments. Environmental and social goals are, therefore, not only inexorably intertwined with economic goals in the decision processes and are essential to the long-term sustainability of agribusiness in the region, but also vary based on the role of the decision maker (owner vs. renter). Policy makers need to consider farmers' risk preferences and any heterogeneity between renters and owners when designing farm policies that address environmentally unsustainable practices and that promote other practices where environmental and social impacts are also considered.

1.2. Literature Review: Prospect Theory and Role Influences

Sustainable agriculture depends on agribusiness decisions that are frequently made under conditions of uncertainty and incomplete information, and are influenced by decision makers' differences in risk preferences and perceptions. Land use and agricultural management decisions involve risks connected to global market prices, climate events, such as rainfall or droughts, outbreaks of pests and diseases, and the introduction of new technologies. Most efforts to study risk attitudes among farmers in the developing world have been based on neoclassical economics and have relied on expected utility (EU) theory [35], which assumes that risk preferences are consistent between domains and across time, and are adequately captured by the concavity of the utility function. However, Kahneman and Tversky [36] show that risk preferences are better explained by prospect theory (PT), which accounts for the differences in risk preferences in the domain of gains versus losses, as well as the strong preference for certainty by decision makers.

The utility function is based on objective probabilities in EU theory, while PT allows for the influence of subjective probabilities, where individuals can place different decision weights on different probabilities. As extreme weather events become more frequent and acute, understanding subjective probabilities and their weighting becomes more relevant to modelling farmers' decisions [37]. PT also includes a reference point, in which the value function has a kink that separates gains and losses. This reference point is dynamic and subjective. Thus, major limitations of EU theory are the lack of consideration of any reference dependence and of probability weighting.

PT states that decisions under uncertainty are made to either ensure gains or avoid losses that, psychologically speaking, loom larger than gains. In PT, risk preferences are characterized by the curvature of the value function and by two additional parameters: Nonlinear weighting of probabilities (or certainty preference) and loss aversion [36]. Specific functions and values used to estimate these parameters are shown in the Results section. Taken together, these three parameters provide a descriptive rather than normative model of decision making. At a first look, PT suggests that options that result in gains (i.e., outcomes above the reference point) will be preferred, even if they lead to negative longer-term environmental or social externalities. However, PT also provides a possible technique to reverse such choices by reframing them—when the negative externalities are presented as certain losses, the option that generates them is less likely to be preferred. Moreover, PT implies that farmers may take big risks to escape losses.

While PT has motivated economists, psychologists, and policy makers to better capture/represent risk preferences to understand behavior and to, subsequently, design more effective policies, field studies eliciting risk measures have primarily characterized risk preferences by one parameter: The curvature of the utility function (See [38] for a review of studies in developing countries). The curvature determines whether the individual is risk averse, risk neutral, or risk seeking. Some articles have gone beyond the curvature to elicit PT parameter values for the curvature of the value function, loss aversion, and probability weighting [37,39–41]. Researchers have estimated correlations between different variables and risk preference parameters [39,42–44]. For example, Tanaka, Camerer and Nguyen (2010) [39] estimated PT parameters and found that (a) people living in low income villages were more loss averse and (b) no statistical differences for risk aversion or probability weighting were detected. Moreover, Liu (2013) estimated risk preference parameters for PT among cotton farmers in China, and found that risk and loss aversion affected farmers' decisions to adopt a new cotton technology [45].

General differences based on land tenure (between renter and owners) have been well-studied [46–48]. In Iowa, Varble et al. (2016) found significant differences between land tenure and the willingness to adopt different conservation practices [49]. In Argentina, Arora and colleagues [28] explored differences between renters and owners on agribusiness goals. They found that, possibly due to underlying psychological differences in the connection with the land, ownership was positively correlated with a long-term environmental focus, whereas land rental was positively correlated with a short-term profitability focus. The deeper connection from actual land ownership changed how losses and gains were framed, suggesting that heterogeneity in the PT variables based on land tenure is likely.

Heterogeneity in risk preferences and the framing of decisions has also been documented based on the role of the decision maker. Whether the decision maker is the producer working the land—and, thus, someone likely to be psychologically connected to the outcome—or a technical advisor who may have a broader perspective and greater psychological distance from the decision [50], can influence risk preferences and choices. Boyles and colleagues [51] found that having distance from the decision (i.e., an advisory role) resulted in a longer-term and global frame leading to a greater willingness to incur smaller short-term losses for a larger longer-term gain. This is true even when advisors were making decisions for themselves, i.e., their own gains and losses were determined by their choices.

Clearly, risk preferences and goal motivations vary depending on land tenure and the role of the decision maker in the agribusiness. What is less understood is the relationship between land tenure and decision making roles on risk preferences and consequent choices. Thus, understanding the underlying PT parameters as they vary by the tenure and role of decision maker in the agribusiness, and how they differ from EU expectations is important if we are to develop policies and decision tools that support decision making for sustainable agriculture.

1.3. Research Hypotheses

The research reported here seeks to answer two main questions: (1) Are Argentine agribusiness decisions under risk consistent with EU theory or, instead, are they better represented by PT, displaying loss aversion and different probability weightings? and (2) is there heterogeneity in preferences (risk aversion, loss aversion, and probability weighting) that can be tied to land tenure and agribusiness role?

Specifically, for the first question, we will test whether EU theory assumptions regarding probability weighting (being linear) and loss aversion (no differences in how gains and losses are perceived) hold true. Given documented findings in the literature that support PT as a descriptive theory of decision making, our alternative hypotheses to counter EU theory assumptions are that agribusiness decision makers do not weigh probabilities linearly, and that they perceive gains and losses differently.

In the second question, we seek to examine the impact of land tenure (renters vs. owners) on PT parameters. To the best of our knowledge, this is the first paper to study risk preference differences between land renters and owners through analyses of PT parameters. Since heterogeneity in risk perspectives and choices may also be tied to psychological and emotional distance from a decision, we explore how agribusiness producers who are farmers, and, therefore, food suppliers, may differ in their PT parameters from those who provide advisory services to those who are farmers/owners.

We examine these questions and test our hypotheses via a lab-in-the-field experiment containing three paper-based exercises with decision makers from agribusinesses in the Pampas. Our hypotheses diverge from traditional assumptions of rationality and utility maximization inherent in EU theory to account for the heuristics and biases that have been well documented in human decision making [52]. We test the validity of "Homo economicus", a rational maximizer of self-interest [53], as a decision maker in a real world setting to create better descriptive models of agribusiness decision making.

Research on agricultural production, farm management, and policies have traditionally been based on assumptions of rationality and EU theory [54]. In this research, by testing the underlying assumptions, we question the true impact of "sustainability-oriented" policies and programs: Can tax incentives to encourage investments in long-term climate change mitigation and adaptation really work if the decision maker views the choice as a short-term certain loss rather than as a long-term gain? Perhaps a better understanding of actual risk preferences and the influence of role and land tenure on risk preferences could result in policies, programs, and tools that are more likely to frame the mitigation and adaptation choices as the more palatable options. The following sections discuss our methodology, experimental materials, results, and the resulting theoretical and policy implications. It bears noting that though grounded in behavioral economics, our methods, analysis, and interpretations borrow from psychology and management as sustainable decision making by agribusinesses requires such an interdisciplinary approach.

2. Materials and Methods

2.1. Experimental Design and Games

PT describes decisions under risk by three parameters, including the curvature of the value function, loss aversion, and probability weighting. This experiment was designed following functional forms for utility, probability weighting, and the value of the prospect as described by [55]. The underlying value function is a piece-wise function for gains and losses for the outcome, x:

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

where σ describes the curvature of the value function and λ describes the degree of loss aversion. This value function has a kink at zero, where $U(x) = 0$. If $\sigma < 1$, the value function is concave in the gain domain, and convex in the loss domain. If $\lambda > 1$, an individual is loss averse and weighs losses λ-times more than gains of the same magnitude, which is reflected in a steeper curvature of the value function in the loss domain. The probability weighting function is:

$$w(p) = \frac{p^{\alpha}}{\left(p^{\alpha} + (1-p)^{\alpha}\right)^{\frac{1}{\alpha}}} \tag{2}$$

where p is the objective probability of an event. PT considers that individuals make decisions based on subjective probabilities, weighing objective probabilities. If $\alpha < 1$ ($\alpha > 1$), the individual overweighs (underweighs) small probabilities and underweighs (overweighs) large probabilities. If $\alpha = 1$, $w(p)$ becomes linear, it matches EU theory. Faced with a prospect that pays, x, with a probability, p, or pays, y, with a probability, $1-p$, the value of the prospect (A or B, see below) is defined as:

$$V(prospect) = w(p)U(x) + (1 - w(p))U(y) \tag{3}$$

When $\alpha = 1$ and $\lambda = 1$, the above equations collapse to match EU theory. However, for all other values, EU theory falls short. An individual faced with two prospects, A and B, containing different lotteries, chooses option B as long as $V(B) \geq V(A)$.

2.2. Procedures and Participants

Experimental data was collected from 341 AACREA (Asociación Argentina de Consorcios Regionales de Experimentación Agrícola) members in the Pampas, which provides a representative sample of active farmers and/or advisors who are highly influential in the region [56]. Each participant is connected to the decision-making process in an agribusiness. Most participants are the primary decision makers in the agribusiness, though a small minority provide advice. For the remainder of the article, we use the term farmer and agribusiness decision maker interchangeably. AACREA members farm in areas with relatively homogeneous ecological and production characteristics and tend to have an education that is above average [56]. At the time the experiments were conducted, AACREA had about 1600 members. Paper-based exercises were distributed to all members (organized into groups of 8–10 agribusinesses from a region and who have similar production systems) by AACREA technical advisors (the professionals who coordinate group interactions and information exchanges, and who introduce technical or management innovations to group members).

Each farmer completed a series of paper-based exercises eliciting PT parameters, as well as some demographic questions. The experimental games are summarized in Figures 1–3. Exercise forms were collected by the groups' advisors and sent to AACREA Headquarters for coding and quality control.

Option A		Option B	
Probability	Payment	Probability	Payment
●●●●●●●	200	●●●●●●●●●	100
○○○	800	○	Z

Figure 1. This figure summarizes Exercise 1, which was presented to participants. Each participant was asked to choose a value of Z at which Option A is no longer preferred to Option B. Possible values for Z are: 1360, 1120, 1240, 1300, 1440, 1540, 1660, 1800, 2000, 2200 and 2600.

Option A		Option B	
Probability	Payment	Probability	Payment
●	600	●●●	100
○○○○○○○○○	800	○○○○○○○	Z

Figure 2. This figure summarizes Exercise 2, which was presented to participants, and follows the same procedure as Exercise 1. Possible values for Z are: 1080, 1120, 1160, 1240, 1300, 1360, 1440, 1540, 1660, 1800, 2000, 2200 and 2600.

Option A		Option B	
Probability	Payment	Probability	Payment
●●●●●	-600	●●●●●	-900
○○○○○	1000	○○○○○	Z

Figure 3. This figure summarizes the Exercise 3, which was presented to participants, and follows the same procedure as Exercise 1. Possible values for Z are: 1050, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2500, 3000, 3500 and 4500.

In each game, a participant was presented with two prospects, *A* and *B*, and with specific probabilities for each prospect, which were depicted by black and white balls, as illustrated by Figures 1–3. For each game, the participant was asked to choose the value of Z that would make him/her choose Option B instead of Option A, or switch from Option A to Option B. The probabilities vary across, but not within, the three games. Games 1 and 2 are about gains, while Game 3's prospects include both positive and negative payments. Given the choice of Z for each game, values of α, σ, and λ

are assigned based on predetermined tables such that they satisfy the condition that $V(B) \geq V(A)$ for each game following Equations (1)–(3).

3. Results

3.1. PT vs. EU

After assigning a value for α, σ, and λ to each participant, we computed summary statistics, which are depicted in Table 1:

Table 1. Summary Statistics of Prospect Theory (PT) Parameters.

Parameter	Min	Median	Mean	Max
σ	0.1	0.6	0.6	1.3
α	0.1	0.6	0.7	1.4
λ	0.2	2.2	2.5	7.1

Table 1 shows that the average farmer has a concave (convex) value function in the gain (loss) domain. Moreover, the average farmer overweighs small probabilities and underweighs large probabilities as the average α is below one. Lastly, we observe that the average farmer is loss averse, putting two and a half times more weight on losses than gains, on average.

To place our findings in context, we compared our results with other studies. For comparison, Tanaka, Camerer, and Nguyen (2010) estimated average values for (σ, α, λ) as (0.59, 0.74, 2.63) and (0.63, 0.74, 2.63) among southern and northern Vietnamese villages, respectively [39]. Liu (2008) estimated average values of (0.48, 0.69, 3.47) for (σ, α, λ) [45]. Moreover, Bocquéh, Jacquet, and Reynaud (2013) found average values of (0.51, 0.65, 3.76) for (σ, α, λ) among French farmers [37]. Therefore, the average parameter values in our sample are in line with previous studies.

To study our first research question, we tested whether the α and λ parameters from the experimental results were equal to those assumed by EU theory. Moreover, we tested for risk neutrality versus risk aversion. We performed one-sample t-tests to test the following pairs of null and alternative hypotheses: (1) $H_0: \ \sigma = 1$ versus $H_a: \sigma < 1$; (2) $H_0: \ \alpha = 1$ versus $H_a: \alpha < 1$; and (3) $H_0: \ \lambda = 1$ versus $H_a: \lambda > 1$. The first pair of hypotheses tested for risk neutrality with an alternative hypothesis of risk aversion if we assumed that risk preferences were only captured by the curvature of the utility function, as in EU theory. The second and third pairs tested whether EU theory holds, meaning that the probability weighting was linear and that there are no differences between gains and losses (i.e., no loss aversion). We reject the null hypothesis for each pair, with p-values below 0.0001 for the three t-tests. We conclude that agribusiness decision makers are risk averse and that our results are statistically different from EU theory.

We also performed Wilcoxon signed-rank tests for the same pairs of hypotheses to confirm our results using a non-parametric statistical hypothesis test. We confirm our results, as we reject the null hypothesis for each pair, with p-values below 0.0001. Our hypothesis testing implies that Argentine agribusiness preferences are better captured by PT than EU theory, as decision makers appear to be loss averse and as they overweigh small probabilities and underweigh large probabilities. Furthermore, we observed that the average farmer has a diminishing value function in the gain domain and an increasing value function in the loss domain. We also report the median values to further show that they are not close to the EU theory or risk neutrality assumptions, and conclude that Argentine agribusiness behavior is better captured by PT. Agribusiness decision makers are, on average, risk averse, loss averse, and overweigh small probabilities and underweigh large probabilities.

3.2. Heterogeneity

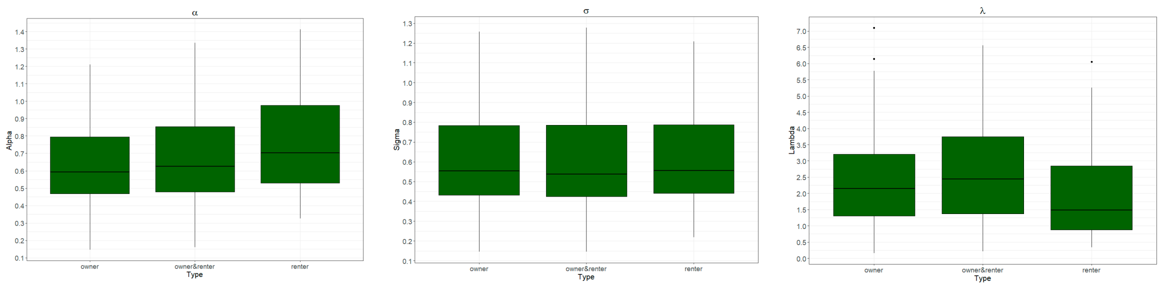
3.2.1. Land Tenure

One of the contributions of our article is to study the heterogeneity in risk preferences between renters and owners, and between producers and advisors to understand any heterogeneity that may influence the way agribusinesses adapt to climate change and attain sustainability in their crucial function as food suppliers. We began by identifying decision makers by land tenure: Owners only, renters only, and those who are both owners and renters (owners + renters), as shown in Table 2.

Table 2. Distribution of Owners and Renters.

Owner Only	Owner + Renter	Renter Only
117	160	40

Table 2 excludes participants who are only advisors, i.e., they only provide advice, but do not themselves own and/or rent land, for a total of 317 decision makers. For the current analysis, we focused on this subsample, as these are the primary decision-makers. Table 2 shows that most agribusinesses own and rent land at the same time, thus, the decision makers make choices on different plots of land. To explore differences between the three groups, we created three box plots for each PT value, as illustrated by Figure 4:



(**a**) (**b**) (**c**)

Figure 4. Box plots comparing the distribution of PT parameter values between, from left to right within each panel, owners, owners & renters, and renters: (**a**) PT parameter α; (**b**) PT parameter σ; and (**c**) PT parameter λ.

Panel (a) shows similar boxes for owners only and for those who are owners and renters at the same time. The box plot for renters only stands out as the most different in that panel, with higher quartiles. Moreover, the median is closer to one for renters, meaning that renters are closer to EU theory assumptions. At first glance, owners only and owners + renters appear to overweigh more small probabilities than renters only. Moreover, owners only and owners + renters seem to underweigh more large probabilities than renters only.

Switching to the curvature of the value function, we observed that the three box plots are very similar in Panel (b) from Figure 4. The first three quartiles are below one for every type, showing that most farmers have a concave (convex) value function in the gain (loss) domain. Lastly, Panel (c) shows differences between the three boxes, with owners and renters with the highest median and third quartile, and renters with the lowest quartiles overall. We observed that farmers who are both owners and renters appear to be more loss averse. Comparing owners only to renters only, we noticed more loss aversion among owners than renters. While we know that the connection to the land manifests differently for owners and renters [28], tenants start the cropping cycle in the loss domain, as having paid out the rent, they incur high upfront costs. Thus, renters should be more willing to do what needs to be done to overcome the initial loss [28], which is confirmed by the lower degree of loss aversion.

To complement the visual analysis, we conducted three Welch two-sample t-tests to compare the average between renters only versus owners and owners + renters: (1) $H_0 : \alpha_{renter} = \alpha_{owner}$ versus $H_a : \alpha_{renter} \neq \alpha_{owner}$; (2) $H_0 : \sigma_{renter} = \sigma_{owner}$ versus $H_a : \sigma_{renter} \neq \sigma_{owner}$; and $H_0 : \lambda_{renter} = \lambda_{owner}$ versus $H_a : \lambda_{renter} \neq \lambda_{owner}$. The subscript for owners includes both owners and owners + renters. We confirmed our visual analysis. For the first pair, we reject the null hypothesis and find that the average among renters, $\alpha_{renter} = 0.77$, is statistically significantly higher than the average among owners, $\alpha_{owner} = 0.66$, with a p-value = 0.017. Hence, renters overweigh (underweigh) less small (large) probabilities relative to owners. For the second pair, we fail to reject the null hypothesis, and find that the average among renters, $\sigma_{renter} = 0.61$, is not statistically different than the average among owners, $\sigma_{owner} = 0.62$. For our third test, we reject the null hypothesis, as the average among renters, $\lambda_{renter} = 2.01$, is statistically different from the average among owners, $\lambda_{owner} = 2.61$, with a p-value = 0.16. Hence, renters only are less loss averse than owners, as they weigh losses twice as gains, while owners weigh losses 2.6 times more than gains.

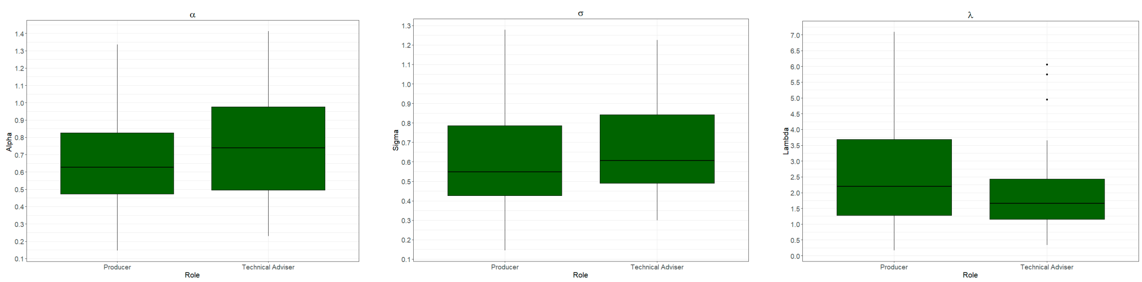
3.2.2. Producers Versus Advisors

We also seek to understand differences between producers and advisors, with the latter as those who advise producers. Here, we include technical advisors who do not own and/or rent land, as well as advisors who own and/or rent land. The paper-based exercises included a question that asked participants to identify themselves as producers or advisors. Table 3 summarizes the distribution among both occupations.

Table 3. Distribution of Producers versus Advisors.

Producers	Advisors
306	35

We note that our sample consists mostly of producers. While we only observe 35 advisors, we want to understand their behavior as they play a crucial role advising agribusinesses about new technologies, adaptation strategies, and conservation practices to attain sustainability. As with land tenure, we first explored any difference visually, as shown in the box plots in Figure 5.



(**a**) (**b**) (**c**)

Figure 5. Box plots comparing the distribution of PT parameter values between, from left to right within each panel, producers and advisors: (**a**) PT parameter α; (**b**) PT parameter σ; and (**c**) PT parameter λ.

Panel (a) shows that technical advisors are closer to EU theory as the median is closer to 1. On the other hand, producers appear to overweigh more small probabilities relative to technical advisors. They also underweigh more large probabilities relative to advisors. Hence, the contrast between the gain and loss domains is more pronounced for producers relative to advisors. We conjecture that producers tend to care more about low probability events, such as droughts or floods, relative to advisors, who know different farms and learn about new technologies and farming strategies. For the curvature of the value function, producers appear to have a steeper value function relative to advisors.

Lastly, Panel (c) shows that producers are more loss averse than advisors. Since producers primarily work the land, they may feel more connection to their farm compared with advisors who see numerous farms. The quartiles for advisors are closer to each other, but we observe a few outliers at the top of the distribution. We observe that producers have a much steeper value function in the loss domain relative to advisors. These parameters suggest that producers are willing to take bigger risks to overcome losses relative to advisors.

Following the same methodology as in Section 3.2.1, we performed three Welch two sample *t*-tests to compare the averages between producers and advisors: (1) $H_0 : \alpha_{producer} = \alpha_{advisor}$ versus $H_a : \alpha_{producer} \neq \alpha_{advisor}$; (2) $H_0 : \sigma_{producer} = \sigma_{advisor}$ versus $H_a : \sigma_{producer} \neq \sigma_{advisor}$; and $H_0 : \lambda_{producer} = \lambda_{advisor}$ versus $H_a : \lambda_{producer} \neq \lambda_{advisor}$. For the first test, we found that the average among producers, $\alpha_{producer} = 0.66$, is not statistically different than the average among advisors, $\alpha_{advisor} = 0.74$, with a p-value = 0.132. While producers have a smaller probability weighting, we cannot reject the null of equal means between both groups. For the second test, we also fail to reject the null hypothesis. We find that the average among producers, $\sigma_{producer} = 0.61$, is not statistically different than the average among advisors, $\sigma_{advisor} = 0.68$, with a p-value = 0.173. On the other hand, for the third test, we reject the null hypothesis and conclude that the average among producers, $\lambda_{producer} = 2.54$, is statistically different than the average among technical advisors, $\lambda_{advisor} = 2.05$, with a p-value = 0.049. We conclude that producers are more loss averse than advisors, since producers weigh losses 2.5 times more than gains while advisors weigh losses twice as much as gains. As advisors are less loss averse, their advice will reflect this difference, and it will be interesting to see if producers are open to a recommendation that may make them uncomfortable due to their stronger loss aversion.

In summary, our analysis allows us to better understand agribusiness decision makers and to identify differences in human behavior based on land tenure and agribusiness role. In this Results section, we find that renters only overweigh small probabilities less than owners only and owners + renters. Similarly, renters only underweigh large probabilities less than owners and owners + renters. Furthermore, we find that renters are less loss averse than owners and owners + renters. We find similar differences between advisors and producers, with producers being more loss averse than advisors.

4. Discussion

Our results illustrate that agribusiness decision makers are better represented by PT parameters than EU theory—they treat gains and losses differently and use subjective probabilities of outcomes: They are quite loss averse and are more likely to overweigh small probabilities. Some of these divergences from EU theory are further nuanced based on the role of the decision maker (producer vs. advisor) and land tenure (owner vs. renter), as summarized in Table 4. In all cases, however, the agribusiness decision makers we studied do not act like *Homo economicus*, providing evidence for all our hypotheses.

Table 4. Summary of Results.

Hypothesis	Results
Expected Utility Theory versus Prospect Theory	Prospect theory better captures risk preferences among Argentine agribusiness decision makers, who are found to be loss averse and who overweigh (underweigh) small (large) probabilities.
Heterogeneity in Risk Preferences based on land tenure and agribusiness role	Owners only and Owners + Renters (Producers) are more loss averse than renters only (advisors). Owners only and Owners + Renters overweigh (underweigh) more small (large) probabilities than renters only.

Our results are in line with studies on risk preferences that estimate the three PT parameters. Tanaka, Camerer, and Nguyen (2010) found that individuals are loss averse and overweigh (underweigh) small (large) probabilities in Vietnamese villages [39]. Liu (2010) and Bocquéh, Jacquet, and Reynaud (2013) found similar results among cotton farmers in China [45] and among French farmers [37], respectively. However, Chinese cotton farmers and French farmers are more loss averse than Argentine farmers or Vietnamese individuals, placing more weight on losses than gains. Our article contributes to the literature by studying risk preferences in a market-oriented country that is a major contributor to the global food supply and that lacks agricultural subsidies and agricultural insurance. Given these conditions, farmers face losses differently than farmers in countries with subsidies and insurance for farmers. Hence, understanding their risk preferences becomes extremely relevant for any farm policies or programs. To the best of our knowledge, no other articles have studied heterogeneity in risk preferences based on land tenure and agribusiness role, which prevents us from comparing our specific results to other studies. Therefore, our article also contributes to the literature by connecting risk preferences with land tenure and agribusiness roles.

Our paper-based exercises were context independent, and, as such, the deviations from EU theory can be thought of as baseline levels. There is evidence in the literature that context can change how decisions are spontaneously framed [57] and outcomes are evaluated [58]. Thus, it is important to consider how the high levels of observed loss aversion may manifest in choices when there is greater unpredictability in the context. Numerous agribusiness decisions occur under conditions of high uncertainty caused by unpredictability in decision drivers, like the commodity prices of soybean and wheat, and increases in extreme weather events due to climate change. Here, a loss averse, risk averse farmer who is more likely to overweigh the small probability of a drought may choose options that ensure a short-term gain while ignoring the drought's costlier longer-term environmental and social consequences.

One such example prevalent in the Pampas is the decision to grow (or not grow) cover crops to manage the depth of shallow groundwater. Cover crops are not intended to be harvested. Instead they are planted to enhance soil properties, prevent erosion, and increase water consumption by increasing the time there is a crop in the ground, thus, lowering water table depth (WTD) and decreasing flooding risks [59]. However, cover crops are not as prevalent as researchers/observers think that they should be, especially given the documented increase in WTD due to the switch from mixed pasture/crops to continuous agriculture [33]. This is, in part, due to the perception that droughts are more disruptive, leading to greater losses [1]. As a result, the small probability of a drought is overweighed in the decision process, and the loss averse decision maker—wishing to avoid droughts at all costs—chooses not to plant cover crops. Inadvertently, the agribusiness takes on an additional risk of flooding. Sustainable agriculture would require the decision maker to attempt to manage the groundwater level to avoid droughts and floods by considering both phenomena appropriately. Knowing that farmers are less likely to plant cover crops due to their risk preferences, policy makers can design behavioral nudges to make the potential losses from high WTDs and floods more salient. The goal of the nudges would be to balance the contrast between flood and loss perceptions.

The heterogeneity between owners and renters similarly influences decision making and sustainable agriculture. Land rents are typically due and paid upfront. Thus, renters begin a cropping cycle in the domain of losses, which makes them likely to be more risk seeking. Soybean is the lower cost, higher profit crop, and, as such, is frequently cultivated by renters without rotation. This trend towards monoculture is further exacerbated by the minimal use of fertilizer (an expensive input in Argentina) by renters. There is a greater willingness to take on the risks of monoculture and lack of replacement of nutrients to ensure the initial loss is covered by renters. An interesting caveat is that although land leases are typically one-year, when there is a multi-year lease, renters will use fertilizer during all but the last year of the lease to minimize the potential total loss [28]. The monoculture trend has not substantially impacted yields yet due to technical innovations, masking the negative impact in the form of gradual soil nutrient depletion.

Similar differences in loss aversion between producers and advisors suggest that producers tend to be more averse to losses, showing a sharper contrast between their gain and loss behavior. As advisors are exposed to different farm plots, technologies, and management practices as they interact with multiple agribusinesses, they may feel less connection toward the land. Advisors frequently introduce new technologies and practices to agribusinesses, and their decision-making processes play a critical role in promoting sustainability and climate change adaptation. As with the example of cover crops, an advisor will be more willing to recommend this practice than producers, who may not be as willing to adopt this practice. If producers trust and follow their advisors, these recommendations are more likely to be implemented by producers even if they may make them uneasy due to stronger overall risk aversion.

One limitation of this research is that it does not assess the reference point—a central issue in PT. It is the reference point that determines whether a decision is in the domain of gains or of losses. Without this understanding of how decision makers distinguish between gains and losses, it is difficult to construct policies, programs, or tools that can assist in making more sustainable management and adaptation decisions under risk. The reference point is a dynamic quantity that is adjusted and constructed based on the context of the decision [60]. For example, agribusinesses often adjust their reference point based on previous year performance, as well as expectations of future rainfall or commodity prices [61]. The reference point may also be impacted by social influence, where comparisons with relevant peers can result in adjustments. These comparisons need not be economic—they can be environmental (quality of my land) and social (status in the community, contribution to local social capital). Thus, understanding how reference points are constructed and dynamically adjusted is important to the creation of policies, programs, and tools that support sustainable agriculture.

Using PT to capture risk preferences to better understand how decisions are made under conditions of risk is essential to the overall sustainability of agribusinesses and the agricultural system. To attain sustainability in the face of more extreme weather events and considering loss aversion, agricultural agencies and policy makers can design nudges that make the environmental loss more salient. As owners and producers appear to be more loss averse and as owners tend to contrast more gains and losses, they should be more influenced by the aforementioned nudges and be willing to change their behavior. By understanding differences in risk preferences, environmental campaigns and programs can be better targeted to attain sustainability.

Agribusinesses in Argentina should be fundamentally triple bottom line (profit, planet, people) achievers—to ensure their survival, they must ensure profitability while maintaining the environmental quality of their land for agricultural activities, and building social capital to ensure local knowledge is not lost. Though many act to do so, others fall short, in part due to most agribusiness decisions being made under conditions of risk and incomplete information. Perceptions of risk, probability, and outcomes play a large role in such decisions where concrete data is missing. PT parameters better capture these perceptions and tendencies, and suggest that, due to a strong desire to avoid losses, decision makers have a greater short term focus. As a result, immediate economic outcomes are more salient, and environmental and social investments are framed as costs rather than long-terms gains. These parameters illustrate that certain assumptions are made by decision makers that may inherently contradict each other, preventing higher levels of agribusiness sustainability. This research provides some insights that can be used to design policies, programs, and tools that assist agribusinesses in better managing the contractions across the triple bottom line to ensure greater sustainability.

Author Contributions: The three authors contributed to the conceptualization of the paper. P.A. led the introduction, background, current research and hypotheses with input from J.G.-R. and G.P. Within Materials and Methods, J.G.-R. led the Experimental Design and Games subsection that describes the methodology and models, with feedback from P.A. and G.P. Moreover, G.P. led the subsection on Procedures and Participants and helped collect and check the field data. The data analysis and data visualization were performed by J.G.-R. The Results section was led by J.G.-R. with input from P.A. and G.P. The three authors discussed the results, their interpretations, and their implications that are summarized in the Discussion led by P.A. with input by J.G.-R. and G.P. The three authors participated in the writing, review, and editing process. Lastly, the funding acquisition was done by G.P. and P.A.

Funding: This research was funded by NSF Grant # SES-0345840 to the Center for Environmental Decisions (CRED), Columbia University, and by NSF Grant # CNH-1211613 to the second and third authors.

Acknowledgments: We thank Elke Weber (formerly at Columbia University), who designed the exercises to elicit PT parameters. We also thank the members, technical advisors and staff of AACREA, who willingly participated in the decision exercises and helped us to collect and check the data.

Conflicts of Interest: The authors declare no conflict of interest.

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