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Cognitive Heuristics and Farmers' Perceptions of Risks Related to Climate Change

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Cognitive Heuristics and Farmers' Perceptions of Risks Related to Climate Change¹

A significant component of the larger concern surrounding climate change due to greenhouse gas emissions is the potential for negative effects on agricultural productivity and farmer welfare across the globe. Changes in rainfall patterns and temperatures have a direct effect on the mean and variance of yields and an indirect effect via increased susceptibility to pests and disease. While there is uncertainty as to the magnitude or timeline of climate change and the corresponding effects, a growing literature has emerged investigating the potential effects of climate change on the livelihood of farmers in developed and developing nations. For policy makers to design programs to assist farmers dealing with climate change it is critical to not only understand the impact on agricultural production, but to also understand how farmers perceive these impacts and respond to them. Farmers facing productivity shocks from climate change possess a menu of potential strategies such as changes in planting and harvesting timelines, input use, variety selection, insurance purchases, and exiting the market.

However, which strategies farmers pursue not only depends upon the actual effects of climate change, but also on how they perceive and cognitively process their experiences and update their perceptions of climate risk. As has been widely explored in the psychology literature and more recently in the economics literature, when individuals are faced with complex and uncertain decision situations they use heuristic rules to simplify mental tasks into simpler ones. Heuristics are believed to play a role in determining risk perceptions in the context of climate change (Rachlinski, 2000; Sunstein, 2006; Weber 2006), but little empirical evidence has

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been provided thus far in the economic literature. An exception is represented by Diggs (1991) who investigates farmers' use of heuristics to form qualitative judgments on climate change.

In this study we report the results of a series of experiments assessing farmers' perceptions of climate change risks and investigate whether farmers rely upon heuristics to form their quantitative assessment of specific weather and pest risks that are affected by climate change. In our study we focus on three heuristics that have been identified in the social psychology literature: (1) the availability heuristic which is a mechanism by which individuals retrieve examples of memorable past events to assess future risks, (2) the representativeness heuristic where individuals judge the probability of little known events by the degree of similarity to other better known events, and (3) biased assimilation where individuals tend to embrace evidence that supports their beliefs and reject evidence against them. These three particular heuristics were selected for analysis because they all have a direct effect on how rapidly a farmer pursues alternative strategies to cope with the effects of climate change on agricultural productivity. Understanding how quickly farmers adapt and the hurdles to adaptation are critical for designing farmer outreach programs that can assist in a changing environment.

To assess farmers' perceptions of climate change risks and use of heuristics we conducted a set of experiments with 195 farmers operating apple orchards or grape vineyards in Trentino, Italy. Data was collected via computer-assisted-personal-interviews and consisted of several components including: (1) an elicitation of short- and long-run future risk perceptions via the exchangeability method (Baillon, 2008), (2) a collection of data on historical farm crop losses, (3) general survey questions on farm and farmer characteristics including a set of probability tasks adapted from Fischbein and Schnarch (1997), and (4) survey questions eliciting attitudes

and beliefs regarding climate change. Using the data collected from the experiments, regression analysis provides several key insights on farmers' perceptions of climate change risk and on the use of heuristics to form perceptions of farm risks related to climate change.

The remainder of the paper is organized as follows. In the following section an overview of the experiment procedures is provided. Then a summary of the sample characteristics and responses to key experiment questions is presented and analyzed. This is followed in the next section by econometric analysis of the experiment data to assess farmers' beliefs in climate change and use of heuristics. Finally, we conclude.

Survey and Experiments

To assess farmers' perceptions of climate change related risks and the use of heuristics, in the spring of 2011 we conducted a set of experiments with a sample of farmers operating apple orchards or grape vineyards in the Province of Trento, Northern Italy. With an annual production value of over 345 million Euros, apples and wine grapes are by far the two most important crops grown in the Province of Trento (Servizio Statistiche 2007). To assess farmers' perceptions we focused on two key crop loss hazards whose gravity has been predicted to increase with climate change: powdery mildew and hail for grape growers and apple dieback and hail for apple farmers. Powdery mildew is a fungal disease that affects grapes and can significantly reduce crop yields and represents a growing threat as temperatures increase and rain precipitation becomes scarcer. Apple dieback describes a condition where trees die prematurely due to opportunistic pathogens that colonize trees in climatic and agronomic adverse conditions and is projected to increase as a threat as extreme winter conditions become more frequent. Damage from hail is the single most important cause of revenue losses for apple farmers in the region and to a lesser

degree for grape growers. The gravity and frequency of hail precipitation is also expected to increase in future climate scenarios for the region.

The experiments were conducted via computer assisted face to face interviews to elicit farmers' perceptions of crop disease risk and hail risk in the short-run (the upcoming growing season, 2011) and in the long-run (a more remote future growing season, 2031). It is the long-run perceptions that will be used to investigate whether farmers have quantitatively detectable perceptions of climate change related risks. Obviously climate change spans a much longer period than the one we considered, but we were constrained in the choice of the long-run timeframe by practical reasons. Preliminary focus groups indicated that twenty years is an ideal long-run time frame to preserve farmers' ability and willingness to formulate beliefs about future events, whereas a longer time horizon would fail to engage farmers in the task.

Farmers' perceptions were elicited via the exchangeability method (hereafter EM); a method based on the idea of exchangeable events (de Finetti 1937). EM has been recently proposed by Baillon (2008) as a promising risk elicitation procedure and has been applied by Cerroni and Shaw (2010) and Cerroni, Notaro and Shaw (2011) to elicit perceived environmental risk due to pine beetle infestations in Texas forests. With the EM, subjects are faced with a series of binary choices between prospects used to identify one or more points on an individual's cumulative distribution over a given event. In our study, the events under investigation are the province-level percentage of apple (or wine grapes) value lost to hail, the province-level percentage of apple trees affected by dieback, and the province-level percentage of grape bunches affected by powdery mildew, in the short- and long-run.² It is critical to note that the

² Preliminary focus groups indicated that farmers naturally express hail damage in terms of the percentage of the apple (or wine grape) value that is destroyed by hail, apple dieback damage in terms of the percentage of apple trees affected by the syndrome and powdery mildew damage in terms of the percentage of grape bunches affected by

events under investigation refer to the province-level and not to individual farm losses. To identify the contribution of climate change to long-run risk perceptions, we selected a common risk event across farmers to remove confounding factors, due to different objective risks and current conditions that are difficult to control for.³

Baillon (2008) provides a detailed explanation of the EM and in what follows we only briefly describe the EM procedure in our context. The first step of the EM establishes the lower and upper bound of the event space, e.g., the range of potential crop value losses to hail in 2011. For a farmer who assigns positive probabilities to the entire state space the lower and upper bounds are 0% (no damage) and 100% (total damage) respectively, otherwise they lay in the interior of the state space. The second step consists of a series of questions that identify the median estimate which is the 50th percentile of the subjective cumulative distribution. Each question asks the farmer to choose between binary prospects (alternative A or B) that consist of two disjoint intervals of the state space. With bounds being 0% and 100%, for example, the first binary question asks the farmer to decide whether he believes that crop losses are more likely to fall within the lower (alternative A: losses $\leq 50\%$ of crop value) or upper interval of the state space (alternative B: losses $> 50\%$ of crop value). In the subsequent question, the disjoint intervals are adjusted based on the respondent's prior answer. For example, if the respondent chooses the lower interval in the first binary question ($\leq 50\%$), the prospects of the second binary question are $\leq 25\%$ and $> 25\%$. The procedure is repeated until the farmer is indifferent between the two alternatives, i.e., until the farmer assigns the same probability to the two prospects. The

powdery mildew. Since for all three cases, the state space is constrained between 0% (no damage) and 100% (total damage), expressing crop damage as a *percentage* of crop value loss, affected trees or grape bunches conveniently simplifies the implementation of the EM.

³ In the case of crop diseases, for example, short-run objective risk to an individual farmer is likely correlated with the current level of observed damages in the farm (e.g., due to the presence of pest inoculums), while the long-run objective risk is not.

common boundary of the intervals in the last question identifies the median damage (the 50th percentile of each subject's cumulative distribution of crop value loss), which we take to be our risk measure. Each farmer completed the EM a total of four times, once for each type of risk (hail and crop disease), and once for each time period (2011 and 2031). Figure 1 presents a sample choice situation faced by a participant in the EM experiment.⁴

Select (by clicking on it) the alternative (A or B) that you believe is more likely

In my opinion, the percentage of apple value losses due to hail at the province level in the upcoming season (2011) is going to be:

Alternative A	Alternative B
Less than or equal to 50%	More than 50%

Figure 1. Sample Exchangeability Method Choice Scenario

After the EM experiments, each participant provided responses to questions pertaining to their farming background and farm characteristics that could be hypothesized to influence risk perceptions, their income and financial situation, past observations of weather related events and crop losses, their general beliefs and opinion regarding climate change, and their outlook for the future. In addition, farmers completed a set of 8 probability tasks, adapted from Fischbein and Schnarch (1997), which we included to assess farmers' ability to process probabilistic information.

⁴ The original Italian phrasings of the questions in the experiment are available from the authors.

Farmer Characteristics

Table 1 presents a summary of the characteristics of the sample. In terms of farmer attributes, the average age is 45.5 with 23.9 years of farming experience, education is 10.4 years of schooling, and 79% are full time farmers. The average household size is 3.4 members. For the farming operations, the average size is 4.8 hectares with the majority of cultivated land being owned by the operators (74.8%). Farm and farmer characteristics closely match the population of perennial-crop farmers in the region (Servizio Statistica 2007).

The average reported net monthly family income is 2,330 Euro. As a measure of the liquidity of farmers' assets, 62% reported that they would be able to pay 20,000 Euro within 5 days in case of a suddenly encountered unforeseen situation. With regard to the set of 8 probability questions assessing farmers' ability to process probabilistic information, on average, farmers correctly answered 3.3 questions with a standard deviation of 1.3.

Table 1. Farm and Farmer Characteristics

Variable	Mean	Stdev.
Age	45.503	12.760
Farming Experience (years)	23.862	13.641
Full Time Farmer (Yes/No)	0.790	0.409
Education (years)	10.354	2.906
Probability Score	3.349	1.269
Farm Size (hectare)	4.756	2.718
Income (1000 Euro/month)	2.330	1.323
Liquidity Unconstrained (Yes/No)	0.621	0.487
Cultivated/Owned (%)	74.805	29.054
Household Size	3.379	1.205

To understand farmer attitudes and beliefs regarding climate change, farmers were asked several questions. Of the 195 farmer sample, 83% stated that they believe in climate change. Of those who answered positively to believing in climate change, the majority of farmers (about 58%) stated that both natural and anthropogenic reasons are responsible for climate change in

equal measure, 22% believe that climate change is predominantly or exclusively due to anthropogenic reasons, and 19% believe that climate change is mainly or entirely due to natural factors (see table 2).

Table 2. Perceived Cause of Climate Change Among Believers

	% of sample
Due to natural factors exclusively	5.6
Due predominantly to natural factors	14.2
Due to a similar extent to natural and human activity factors	58.0
Due predominantly to human activity factors	19.1
Due to human activity factors exclusively	3.1

Table 3 reports summary statistics of the median damage (our measure of risk) elicited via the exchangeability method for each crop and peril. As can be seen, the average long-run risk (2031) exceeds the short-run risk (2011) and the standard deviations are sizable for all risk types, crops, and time frames.

Table 3. Short Run and Long Run Median Damage

Risk type	Unit of measure	#	2011		2031	
			Mean	Stdev	Mean	Stdev
Hail	% Province level apple value loss	120	21.17	13.02	26.24	15.98
Hail	% Province level grape value loss	75	12.68	10.01	18.65	13.69
Dieback	% Province level apple trees affected by dieback	120	10.47	11.64	11.74	11.86
Powdery Mildew	% Province level grape bunches affected by powdery mildew	75	10.12	10.96	13.27	13.38

Perceptions of Climate Change Risks

In this section we first present an analysis of risk perceptions in the context of beliefs in climate change. Specifically, to investigate the role of climate change in long-run risk perceptions, in this section we test if farmers who believe in climate change show quantitatively higher

perceptions of related hazards than farmers who do not believe in climate change. In table 4, we report the results of several models in which the dependent variable is the long-run median hail damage. If climate change plays a role in long-run perceptions, we would expect, *ceteris paribus*, higher values for the long-run median hail damage elicited from climate change believers than non-believers. Model 1 is the simplest model. It includes a dummy variable identifying climate change believers (*Climate Change*), a crop specific intercept (*Apple – Intercept*) and two variables capturing crop specific short-run median hail damage (*Apple Short-Run Risk* and *Grape Short-Run Risk*). The climate change variable is positive and statistically significant at the 1% confidence level, indicating that climate change contributes to increased long-run perceptions of hail risk.

In model 2, the climate change variable is interacted with the crop type to test whether climate change affects future hail risk perceptions differently across crops. Both variables are positive and significant (10% and 1% level respectively for apples and grapes), with a larger effect of climate change on hail risk for grapes.

In model 3, two additional variables, *Hail Nets* and *Other Reasons*, are included to capture possible additional elements that would potentially affect long-run hail risk perceptions. Specifically, we included farmers' beliefs regarding the future use of physical protection from hail and the use of other tools to protect the crop from hail. Neither variable significantly impacts long-run perceptions, whereas the climate change variable remains positive and significant. To further investigate the potential impact of these additional predictors, we interacted them with the crop type, yielding unchanged results compared to model 3.

In the last three models, socio-demographic characteristics that could be hypothesized to affect perceptions are added. In model 5 we control for experience by including age, the number

of years worked as a farmer (*Farming Experience*) and a dummy identifying full-time farmers. None of these controls are significant at standard levels.⁵

In model 6, we control for education (expressed as years of schooling) and for farmers' understanding of probability events (expressed as the score from the probability task). Both variables are positive and significant at the 5% level indicating that more educated and "probability more talented" persons have higher perceptions of long-run hail risk. Finally in model 7, we add other socio-demographics characteristics, including income, household size and farm size, but find none of them to be significant.

In table 5, we report the results of a similar set of models in which the dependent variable is the long-run median damage due to crop diseases. As for the case of hail, the climate change variable in model 1 is positive and significant lending support to the hypothesis that long-run perceptions are affected by climate change. Disease specific climate change variables in model 2 (*AD-CC* and *PM-CC*) reveal that climate change only affects crop loss risk perceptions due to Apple Dieback but not Powdery Mildew. The divergence in the effect of climate change beliefs on risk perceptions between these two disease risks could be because farmers have a long history of experience with Powdery Mildew. Because of this experience, farmers could be more confident about their ability to control the disease under alternative climatic conditions that might occur in the future. This hypothesis finds support in models 3 and 4, where we account for other potential factors affecting long-run risk. We include *Agronomic Means* to capture farmers' beliefs regarding future availability of chemicals and other agronomics means of disease control and *Farmer Ability* to capture farmers' beliefs regarding their future ability to control disease.

⁵ In unreported regressions, we have replaced the variable *Framing Experience* with dummies capturing short (less than 15 years) and long (30 or more years) farming experience and find them both negative and significant. The less experienced farmers are the most optimistic (reporting lowest long-run damage) and the most experienced farmers, although less optimistic than the first group, are also less concerned than the control group (reporting intermediate long-run damage). The other regression coefficients remain unchanged.

The latter factor is significant. Specifically, the stronger farmers' beliefs that they will acquire additional skills to better control the disease, the smaller the perception of the long-run risk. Matching with intuition, this result is stronger for Powdery Mildew, a better known disease, than for Apple Dieback, a relatively new problem with a high degree of uncertainty for farmers and science as well. In models 5 to 7, we add socio-demographic characteristics and find similar results as for the case of hail risk. Taken together, our results confirm that farmers who believe in climate change have higher quantitative perceptions of future hazards that are related to climate change.

Table 4. Long-Run Hail Risk Regressions

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	0.757 (1.548)	-1.629 (1.586)	0.802 (1.556)	-1.868 (1.603)	5.371 (3.285)	-7.925 (5.357)	-6.867 (5.785)
Apple - Intercept	1.066 (1.822)	3.971* (2.366)	1.113 (1.841)	4.737* (2.395)	1.292 (1.817)	1.575 (1.816)	1.073 (1.929)
Apple Short-Run Risk	1.031*** (0.067)	1.031*** (0.068)	1.030*** (0.068)	1.020*** (0.067)	1.018*** (0.068)	0.989*** (0.072)	0.999*** (0.072)
Grape Short-Run Risk	1.168*** (0.083)	1.172*** (0.081)	1.169*** (0.084)	1.168*** (0.086)	1.152*** (0.088)	1.130*** (0.083)	1.132*** (0.090)
Climate Change	3.344*** (1.161)		3.340*** (1.191)		3.253*** (1.152)	3.362*** (1.177)	3.818*** (1.234)
Apples - CC		2.673* (1.398)		2.831* (1.452)			
Grapes - CC		5.894*** (1.425)		5.556*** (1.355)			
Hail Nets			-0.122 (0.257)				
Other Tools			0.004 (0.455)				
Apple - Hail Nets				-0.238 (0.343)			
Grape - Hail Nets				-0.053 (0.362)			
Apple - Other Tools				0.527 (0.584)			
Grape - Other Tools				-0.866 (0.680)			
Age					-0.088 (0.070)	-0.037 (0.071)	-0.050 (0.072)
Farming Experience					0.027 (0.064)	0.061 (0.068)	0.074 (0.069)
Full Time					-1.359 (1.477)	-1.233 (1.403)	-0.81 (1.474)
Education						0.677** (0.285)	0.662** (0.278)
Probability Score						0.985** (0.409)	1.043** (0.434)
Farm Size							-0.225 (0.216)
Income							0.844 (0.578)
Liquidity							-0.071 (1.345)
Cultivated/Owned							-0.005 (0.022)
Household Size							-0.545 (0.525)
R-Squared	0.735	0.736	0.735	0.740	0.739	0.757	0.764

Table 5. Long-Run Crop Diseases Risk

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	0.316 (1.418)	-1.472 (3.126)	1.902 (1.507)	2.574 (2.841)	2.333 (3.020)	-3.032 (4.070)	-6.228 (4.543)
AD - Intercept	1.114 (1.621)	3.282 (3.261)	0.611 (1.538)	0.151 (3.045)	1.024 (1.623)	0.987 (1.666)	1.891 (1.620)
AD Short-Run Risk	0.749*** (0.087)	0.751*** (0.087)	0.751*** (0.085)	0.738*** (0.086)	0.742*** (0.089)	0.751*** (0.090)	0.728*** (0.092)
PM Short-Run Risk	0.991*** (0.139)	0.992*** (0.133)	0.960*** (0.125)	0.931*** (0.104)	0.987*** (0.136)	0.997*** (0.132)	1.021*** (0.134)
Climate Change	3.184*** (1.162)		2.451** (1.103)		3.224*** (1.175)	3.269*** (1.178)	4.384*** (1.454)
AD - CC		2.668** (1.063)		1.895* (1.107)			
PM - CC		5.121 (3.755)		3.139 (2.962)			
Agronomic Means			-0.186 (0.288)				
Farmer Ability			-1.135*** (0.397)				
AD – Agro. Tools				-0.461 (0.333)			
PM – Agro. Tools				0.475 (0.517)			
AD – Ability				-0.653* (0.363)			
PM – Ability				-2.213*** (0.840)			
Age					-0.075 (0.060)	-0.055 (0.059)	-0.052 (0.061)
Farming Experience					0.062 (0.049)	0.069 (0.057)	0.062 (0.058)
Full Time					-0.007 (1.422)	-0.013 (1.410)	-0.365 (1.447)
Education						0.178 (0.291)	0.090 (0.258)
Probability Score						0.695* (0.405)	0.868** (0.389)
Farm Size							0.073 (0.177)
Income							1.276** (0.642)
Liquidity							-4.360*** (1.555)
Cultivated/Owned							0.025 (0.022)
Household Size							-0.029 (0.475)
R-Squared	0.612	0.612	0.655	0.665	0.614	0.620	0.654

Analysis of Farmer Reliance on Heuristics

In this section, we investigate whether farmers use heuristics to form quantitative assessments of climate change related risks by further analyzing the experimental data on farmers' perceptions of long-run hail risk. We test for three heuristics: availability heuristic, representative heuristic and biased assimilation. Results are reported in table 6.

Availability Heuristic

The availability heuristic is the mechanism by which people retrieve examples of memorable, salient events or use instances that are easy to imagine or recall when assessing future risks. Retrievability of an instance is critical for this type of heuristic and is favored by personal experience with, and the salience of the instance itself (Tversky and Kahneman 1974).

To test for the use of the availability heuristic by farmers forming long-run hail risk beliefs, we exploit information on farmers' past crop losses. In the context of the survey, farmers classified the losses they personally experienced on their farm in 2010 according to the categories: none, mild, medium, heavy and very heavy. *Ceteris paribus*, it would be expected that farmers who have personally experienced more serious crop losses to have higher perceptions of long-run hail risk. One problem with attributing higher degrees of risk perceptions by farmers who have experienced recent crop losses on their farm to the use of the availability heuristic is that personal experience also represents information (used by Bayesian agents to form and update beliefs). To disentangle the two effects, new information vs. availability heuristics, we exploit a sample split between climate change believers and non-believers. Only the first group can potentially use heuristics in forming quantitative perceptions of climate

change risks. Hence, any difference in the effect of past crop loss experiences on long-run perceptions between the two groups can then be attributed to the use of the availability heuristics.

In the first model presented in table 6, two scale variables are included, *CC Past Loss* and *NC Past Loss*, to capture the effect on perceived long-run risk of any degree of own crop loss to hail (0=no loss to 4=heavy loss) of climate change believers and non-believers. We test the hypothesis that for any positive degree of own crop losses, climate change believers have a higher degree of perceptions of long-run aggregate crop value loss than non-believers. With reference to the respective regression coefficients, we test that:

$$H_0: \beta_{CC \text{ Past Loss}} = \beta_{NC \text{ Past Loss}}$$

$$H_1: \beta_{CC \text{ Past Loss}} > \beta_{NC \text{ Past Loss}}$$

A one-sided Wald test with one restriction of the coefficient vector and 184 degrees of freedom rejects the null at the 5% significance level ($p=0.012$). This supports the hypothesis that farmers use the availability heuristic.

Representativeness Heuristic

The representativeness heuristic is typically used when making judgments about the probability of little known events, such as the effect of climate change on long-run hail risk. Specifically, the representativeness heuristic is used by people who judge the probability of a little known event by the degree of similarity to other better known events. We consider the following specific case of potential use of the representative heuristic: farmers judging the effects of climate change on future crop losses by the degree of similarity to the effects of short-run personally observed hail precipitation trends on past crop losses.

By definition, representativeness is the degree to which an event (short-run hail trend) is similar in essential characteristics to its parent population (climate change). To test for the use of this heuristic, we exploit the different degree of similarity between climate change and short-run hail trend between climate change believers and non-believers. For both groups, an observed short-run positive hail trend includes information about future hail risk (independently of the use of the heuristic) but only climate change believers will arguably recognize a higher degree of similarity between climate change and a short-run positive hail trend.

In the central model in table 6, we include three variables identifying: climate change believers who have observed a positive hail trend (*CC Trend*), climate change believers who have not observed a trend (*CC No Trend*), and non-believers who have observed a positive trend (*NC Trend*). Non-believers who have not observed any trend represent the reference group. To provide evidence of the use of representative heuristic in climate change risk perceptions we test that: having observed a positive hail trend increases long-run hail risk perceptions by climate change believers more than the perceptions by non-believers. This hypothesis can be written as:

$$H_0: \beta_{CC\ Trend} - \beta_{CC\ No\ Trend} = \beta_{NC\ Trend}$$

$$H_1: \beta_{CC\ Trend} - \beta_{CC\ No\ Trend} > \beta_{NC\ Trend}$$

A one-sided test with one restriction of the coefficient vector and 183 degrees of freedom rejects the null at the 10% significance level giving support to the hypothesis that farmers use the representativeness heuristic.

Biased Assimilation

According to biased assimilation, an individual's belief structure is sticky in the sense that someone embraces evidence that supports their own beliefs and rejects those that are inconsistent

or contradict their own beliefs (Lord et al. 1979). As a consequence, mixed evidence on a topic which people hold strong beliefs tends to make their views more extreme instead of more moderate (Rachlinski 2000). The degree of uncertainty surrounding the climate change debate and the mixed evidence regarding the connection between changing climatic conditions and crop value losses are well suited to potentially generate biased assimilation. To test for biased assimilation, we make use of the information on farming experience exploiting the fact that, tautologically, farmers with more years of farming experience have been exposed to a larger history of mixed evidence on the effects of varying climatic conditions on crop losses. We hypothesize that climate change believers become increasingly pessimistic about future crop losses (i.e., have higher risk perceptions) as they gain mixed evidence on climate change, whereas farmers who do not believe in climate change will become more and more convinced that crop losses are not going to change in the future.

In the model furthest to the right in table 6, we include three variables identifying climate change believers with 30 or more years of experience (*CC Long Experience*), climate change believers with less than 30 years of experience (*CC Short Experience*) and non-believers with 30 or more years of experience (*NC Long Experience*).⁶ The reference group is represented by non-believers with less than 30 years of experience. We test the following hypotheses:

- (1) Among farmers who believe in climate change, those with 30 or more years of experience will *ceteris paribus* have a higher degree of long-run hail risk perceptions than farmers with less than 30 years of experience.
- (2) Among farmers who do not believe in climate change, those with 30 or more years of experience will *ceteris paribus* have no higher (lower or equal) degree of long-run hail risk perceptions than farmers with less than 30 years of experience.

⁶ Thirty years of experience corresponds with the 75 percentile of the experience variable.

The second of the two hypotheses is supported by the regression results in table 6 where we see that the “NC Long Experience” coefficient is not significantly different from zero implying that non-believers with long experience have risk perceptions that are statistically not different from the perceptions of non-believers with short experience. We are left with testing the first of the two hypothesis, i.e.:

$$H_0: \beta_{CC \text{ Long Experience}} = \beta_{CC \text{ Short Experience}}$$

$$H_1: \beta_{CC \text{ Long Experience}} > \beta_{CC \text{ Short Experience}}$$

A one-sided test with one restriction of the coefficient vector and 184 degrees of freedom rejects the null at the 10% significance level giving support to the hypothesis that farmers are subject to biased assimilation.

Table 6. Analysis of Heuristics

Variable	Availability Heuristic	Representative Heuristic	Biased Assimilation
Apple Short-Run Risk	0.978*** (0.074)	0.991*** (0.078)	0.994*** (0.074)
Grape Short-Run Risk	1.099*** (0.086)	1.108*** (0.086)	1.125*** (0.084)
Age	-0.052 (0.070)	-0.039 (0.072)	-0.044 (0.059)
Farming Experience	0.071 (0.068)	0.067 (0.068)	
Full Time	-1.073 (1.399)	-1.490 (1.386)	-1.504 (1.400)
Education	0.677** (0.292)	0.711** (0.285)	0.655** -(0.277)
Probability Score	1.032** (0.424)	0.925** (0.408)	1.024** (0.407)
Apple - Intercept	0.919 (1.856)	1.319 (1.895)	1.378 (1.886)
CC Past Loss	1.754* (0.910)		
CC Past Loss	-1.159 (1.051)		
CC Trend		5.401*** (1.846)	
CC No Trend		2.887** (1.192)	
NC Trend		2.043 (4.189)	
CC Long Experience			5.250*** (1.957)
CC Short Experience			2.51 (1.647)
NC Long Experience			0.822 (2.021)
Constant	-4.72 (5.223)	-7.822 (5.335)	-5.967 (5.553)
R-Squared	0.758	0.761	0.760

Conclusions

Despite tremendous advances in agricultural production technologies farming remains a risky economic activity due to the influence of nature. Climate change poses significant potential for increasing the inherent susceptibility of farming to weather related damages by increasing the frequency and variability of adverse weather conditions and ultimately resulting in increased

farm losses. As has been explored in this paper, understanding how farmers perceive weather related risks to their livelihood and form their beliefs of future outcomes is critical in order to design policies and outreach programs to assist in a changing climate. Using an experimental approach based upon the concept of exchangeable events, this study presents new evidence on the relationship between farmer attitudes towards climate change and individual-specific perceptions of future farm risks. The evidence strongly indicates that farmers who believe in climate change have higher quantitative perceptions of future hazards to their farming operations that are directly or indirectly related to climate change. Furthermore, using the experimental data, new evidence is presented on how farmers synthesize information and past experiences to form their perceptions of future risks in the presence of the uncertainty surrounding the effects of climate change. Analysis provides strong support for farmer reliance on the availability and representativeness heuristics and biased assimilation.

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