Farmers' Climate Change Risk Perceptions:
An Application of the Exchangeability Method

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Abstract

Using the exchangeability method, we quantitatively elicit Italian farmers' short- and long-run risk perceptions concerning key crop loss hazards whose relevance depends upon climate developments: hail, powdery mildew for winegrowers and apple dieback for apple farmers. We show that long-run perceptions are significantly higher than short-run perceptions and identify climate change beliefs and experience with crop damages as critical factors in explaining this difference. From a policy prospective, our results suggest that an effective outreach service would benefit from offering farmers first-hand on-farm experience with crop risk and a "segmented" approach that takes into consideration farmers' climate change beliefs.

1. Introduction

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 (Dinar and Mendelsohn, 2011). For policy makers to design programs to assist farmers facing threats from climate change it is critical to not only understand the impact of climate change on agricultural production, but to also understand how farmers perceive these impacts and ultimately respond to them (Patt and Schröter, 2008). Indeed, farmers facing risks resulting from climate change (e.g., productivity shocks) possess a menu of potential strategies such as changing planting and harvesting timelines, input use, variety selection, insurance purchases, and exiting the market. However, which adaptation and risk management strategies farmers pursue not only depends upon the actual effects of climate change on agricultural production, but also upon whether and to what extent they perceive the risks and how agricultural risks vary with climate change (Patt and Schröter, 2008; Wheeler et al., 2012). Farmers' willingness to implement adaptation and mitigation policies supported by public authorities and governments also depend upon their beliefs regarding climate change and their perceptions of climate change related risks (Arbuckle et al., 2013a).

This study provides a unique set of quantitative measures of farmers' agricultural risk perceptions and investigate their relationship with farmer-held beliefs in climate change. By providing quantitative measures, this study complements and adds to previous research that has focused on qualitative measures of farmers' perceptions of risks brought about by climate change. Specifically utilizing the exchangeability method (Baillon, 2008), we elicit Italian apple and grape farmers' short- and long-run median crop loss expectations of key agricultural perils (crop loss due to apple dieback, grape powdery mildew, and hail). By combining farmers' risk perceptions elicited via the exchangeability method with survey questions, we are able to assess the impact of climate change beliefs and experience on long-run agricultural risks perceptions.

2. Literature review: Climate change beliefs and agricultural risk perceptions

Recently, a growing body of literature has emerged investigating farmers' beliefs about the existence of climate change, their concerns (risk perceptions) related to climate change, the relationship between climate change beliefs and risk perceptions, and their relationship with farmers' willingness to adapt or to support adaptation/mitigation policies. This literature encompasses an array of studies across diverse groups of farmers in developing and developed countries.

A common element in this recent body of research is the reliance on qualitative methods to elicit farmers' beliefs and risk perceptions (e.g., Likert scales). Farmers' beliefs about the existence of climate change and its causes have been elicited via Likert scales (expressing

degree of agreement) or dichotomous questions (yes/no).[1] Farmers' perceptions of risks due to climate change have been elicited with Likert scale type questions or risk assessment scales. For example, Arbuckle et al. (2013a) use a five-point agreement scale to ask Iowa farmers their degree of personal concern and find that farmers are more concerned about the potential impact of climate change on Iowa's agriculture than on their own farm operation. Of the two components of risk - magnitude and likelihood of harm (Patt and Schröter, 2008) - most studies consider exclusively the effect of climate change on the perceptions of the magnitude of negative outcomes (concerns) while ignoring the effect of climate change on the probability of the negative outcomes. Two studies on risk perceptions distinguish themselves from the others. Rejesus et al. (2013) uses a quantitative three interval scale[2] to ask US farmers to state how climate change will affect the mean and variability of their yields. They found that roughly 70% of producers do not believe that climate change will affect average yields and average yield variability by more than 5%. Le Dang et al. (2014) ask Mekong Delta farmers to assess both the probability (from "extremely unlikely" to "absolutely likely") that climate change will affect different dimensions of their lives (e.g., physical health, income, physical assets, production, social relationships, anxiety about personal loss and happiness) as well as the severity of these impacts (from "not severe at all" to "extremely severe"). They found that farmers perceive a larger effect of climate change on agricultural production, than on physical health or their income.

Several studies also find a positive relationship between climate change beliefs and risk perceptions. For example, Safi et al. (2012) regress a risk perception index based on the eight different risk dimensions and levels against a list of potential determinants and find that climate change beliefs are strong determinants of risk perceptions.

Overall, this emerging body of research focusing on better understanding climate change and farming risks indicates two key results. First, it seems to emerge that farmers who believe in climate change are more likely to express concerns that climate change will negatively affect farming or farming conditions. Second, past experiences with adverse weather conditions (e.g., drought) have a key role in shaping perceptions of similar negative events happening in the future. However, a key missing dimension is to establish weather farmers perceive key agricultural risks to increase in the future even when not prompt to think about climate change and whether these long- vs short-run differences can be attributed to their beliefs regarding climate change.

3. Survey and risk perception elicitation methods

To assess farmers' short- and long-run perceptions of agricultural risks related to climate change, at the beginning of 2011 (before the start of the growing season 2011) we conducted a study 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 Statistica, 2010). Farmers were recruited via the local extension service to represent a significant sample of the local farming population. Farmers were informed that the study had the objective to better understand farmers' perceptions of risk to improve outreach activities. No explicit reference to climate change was used to introduce the study. The study was conducted via computer-assisted face-to-face interviews. In what follows, we provide additional information regarding the investigated agricultural risks, the methods used to elicit agricultural risk perceptions, and the remaining questions included in the survey.

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[1] Examples of statements based on Liker scales and dichotomous questions used to elicit farmers beliefs of climate change are: "I believe that extreme weather events will happen more frequently in the future" (Arbuckle et al., 2013a) and "Do you believe that climate change poses a risk for your region?" (Wheeler et al., 2012).
[2] Increase/decrease >10%, between 5% and 10%, or between 0% and 5%.

3.1 Investigated agricultural risks

In this study of farmer agricultural risk perceptions we focus on two key crop loss hazards whose relevance is related to weather and climate developments: apple dieback and hail for apple farmers and powdery mildew and hail for grape growers.[3]

Damage from hail is the single most important cause of revenue losses for apple farmers in the region (CoDiPra, 2013) and to a lesser degree for grape growers. A recent study by Eccel et al. (2012) shows that the gravity of hail precipitation in the region has increased in the previous 35 years and climatologists have predicted a further increase for the region in the years to come. Apple dieback is a condition where trees die prematurely due to opportunistic pathogens that colonize trees in climatic and agronomic adverse conditions. This peril has been known in the region only for a few years and, although some aspects of this disease are still unknown, this disease has been projected to increase as extreme winter conditions become more frequent in the region (Dallago et al., 2011).

Powdery mildew is a fungal disease that affects grapes and can significantly reduce crop yields. Warmer and dryer seasons provide ideal conditions for the spread of powdery mildew. Although temperatures increases and rain precipitation declines are predicted for the region, a recent study by Caffarra et al. (2012) finds that a concomitant change in the plant phenology (i.e., the anticipation of the harvest date) will leave powdery mildew severity unaffected under the climate projections for the region.

The time reference for the long run risk perception investigation (twenty years) was identified through preliminary focus groups with farmers from the region.

3.2 Agricultural risk perception elicitation: the exchangeability method and the direct question

Farmers' risk perceptions for the upcoming growing season (2011) and for the growing season 2031 were elicited via the exchangeability method, a recently proposed technique by Baillon (2008) and Abdellaoui et al. (2011) for eliciting subjective probabilities without asking subjects to make difficult probability statements or complete likelihood scales. With the EM, subjects are faced with a series of binary choices between prospects and these choices are used to identify one or more points on an individual's cumulative distribution over a given event. The EM has recently been applied by Cerroni and Shaw (2012) and Cerroni, Notaro, and Shaw (2013) to elicit perceived risk related to climate change in two different contexts: undergraduate student' perceived risk of pine beetle infestations in Texas forests and consumers' perceived risk of pesticide residue contamination of applies in Italy.

In our study, the events under investigation are the province-level percentage of apple or wine grape 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. 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 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.

It is critical to underline that we elicit risk perceptions for crop losses at the province-level and not for crop losses on individual farms in order to avoid confounding factors. For example in the case of crop diseases, short-run objective risk to an individual farmer is likely

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[3] We identified these agricultural hazards as suitable for our study in collaboration with climatologists, agronomists, biologists and pathologists of the Edmund Mach Foundation working on an interdisciplinary project (ENVIROCHANGE) assessing the effects of climate change for the region.

to be correlated with the current level of observed damages at the farm level (e.g., due to the presence of pest inoculums), while the long-run objective risk is not. The presence of confounding factors that affect the short-run risk perceptions but not the long-run risk perceptions (or vice versa) would have complicated the interpretation of the role of climate change beliefs on the evolution of risk perceptions over time.

The procedure for implementing the EM to elicit farmer risk perceptions is as follows. 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 2031). The farmer was prompted on the computer screen to state the minimum and maximum crop value losses he believed could possibly occur (e.g., the minimum and maximum crop value losses to hail in 2031). 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 lead to the identification of the median estimate which is the 50th percentile of the subjective cumulative distribution of the expected crop losses. Each question asks the farmer to choose between binary prospects (alternative A or B) that consist of two disjoint intervals of the state space identified in the first step. For example, if the lower and upper bounds elicited in the first step were 0% and 100%, the first binary question would ask the farmer to decide whether he believes that crop losses are more likely to fall within the lower (alternative A: losses ≤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 (≤50%), the prospects of the second binary question are ≤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 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 utilize as our farmer-specific risk perception measure. Each farmer completed the EM procedure a total of four times, once for each type of risk (hail and crop disease), and once for each time period (2011 and 2031). It is important to note that a key advantage of the exchangeability method is that unlike indirect techniques based on external reference events (e.g., probability wheels), the EM does not suffer from biases due to source dependence (Baillon, 2008) and is a straightforward task for subjects to complete. The last question of our survey protocol asked respondents to assess the difficulty of the EM task. About 95% of respondents indicated that encountered no difficulties in understanding and performing the EM task.

To complement the exchangeability method measures and serve as a comparison to the qualitative approaches used in previous research, in the last part of the survey protocol each farmer was asked to assess on a eleven point scale[4] how climate change will affect the risk of crop losses due to hail, powdery mildew, and apple dieback.

3.3 Additional survey questions

In the last part of the survey, several questions were proposed to collect information on factors that could be hypothesized to influence risk perceptions. The first set of questions pertains to farmers' attitudes to climate change. Specifically, we asked farmers to classify themselves as climate-change believers or climate-change skeptics. Additionally, the first group was asked to identify the contribution of natural and anthropogenic causes to climate change, as previous studies have demonstrated the key role of this belief in shaping risk perceptions (e.g. Arbuckle et al., 2013a; Safi et al., 2012).

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[4] Ranging from -5 meaning strong decline in damage, 0 means unchanged, and +5 means strong increase in damage.

A second set of questions pertains to farming background, farm characteristics, and crop history. A third set of questions aims at capturing farmers' exposure to first-hand experience with hail and/or diseases and farmers' exposure to farm risk information. To capture the level of interaction with other farmers in the region (who might influence risk perceptions or be an additional source of information about farm risks), two questions about cooperative participation were included in the survey. Finally, farmers were asked as to complete a set of 8 probability tasks adapted from Fischbein and Schnarch (1997) to assess farmers' ability to process probabilistic information (probabilistic numeracy).

4. Results

4.1 Descriptive statistics: Farmer characteristics and farmer risk perceptions

A summary of farmers' survey responses is presented in Table 1. Farm and farmer characteristics are representative of the population of perennial-crop farmers in the region (Servizio Statistica, 2010). Regarding farmers' first-hand experience with crop losses, a significant percentage, 77%, stated that they had personally seen what they would consider disastrous hail damage to a farm in their region in the past 5 years and 63% had personally seen disastrous disease damage on a farm in their region. Regarding farmers' exposure to information, about 53% of farmers in the sample attended the annual information session by Co.Di.Pr.A, the farmer association that manages crop insurance in the region. As well, on average farmers read booklets or attended 4.69 information sessions by local extension services in the previous year. Finally, the level of interaction with other farmers in the region is very high as over 90% of farmers are members of cooperatives. Within the sample, about a third (29%) are active in their cooperative and serve as a farmer representative involved in the management of their cooperative. With regard to probabilistic numeracy, farmers correctly answered 3.3 questions, which can be considered a remarkable result given the difficulty of the test based on Fischbein and Schnarch (1997).

Table 1. Characteristics of the sample (used as independent variables in the regression)

Variable name	Variable definition	Mean	Stdev
Farm and farmer characteristics			
Age	Years of age	45.50	12.76
Climate Change Belief	1 if farmer believes in climate change	0.83	0.36
Cultivated/Owned	% of cultivated land that is owned	74.81	29.05
Education	Number of years of schooling	10.35	2.91
Farm Size	Number of hectare	4.76	2.72
Farming Experience	Number of years operating as a farmer	23.86	13.64
Full Time	1 if a full time farmer	0.79	0.41
Household Size	Number of members of household	3.38	1.21
Income	Household monthly net income (1000 Euro/month)	2.33	1.32
Liquidity	1 if able to pay 20,000 Euro with 5 days to cover an unforeseen expense	0.62	0.49
Past Disease Damage Experience	1 if farmer has personally seen disastrous disease damage on farms in their region in the past 5 years	0.63	0.48
Past Hail Damage Experience	1 if farmer has personally seen disastrous hail damage on farms in their region in the past 5 years	0.77	0.41
Probability Test Score	# of probability questions correctly answered	3.35	1.27
Information and interaction with other farmers			
Coop Member	1 if a member of a farmer cooperative	0.93	0.25
Coop Representative	1 if farmer representative	0.29	0.45
Co.Di.Pr.A	1 if attended information session by Co.Di.Pr.A in 2011	0.53	0.50
Sessions & Articles	# of recently attended information sessions and articles read	4.69	2.24

4.2 Farmer climate change beliefs

To understand farmer attitudes and beliefs regarding climate change, we asked farmers to identify themselves as climate change believers or skeptics. Of the 195 farmer sample, 83% stated that they believe in climate change. As a comparison with other countries, the share of climate change believers in our sample is substantially higher than, for example, the 65.5% reported by Arbuckle et al. (2013b) for Midwestern U.S. farmers.

Of those who answered affirmatively to believing in climate change, the majority of farmers (58.02%) stated that both natural and anthropogenic reasons are responsible for climate change in equal measure. The share of farmers believing that climate change is predominantly or exclusively due to anthropogenic reasons is 22.23%.[5] Finally, 19.76% believe that climate change is mainly or entirely due to natural factors. These attitudes towards the existence and causes of climate change are reflective of the larger Italian population.[6] As it is the case for other studies in the area (e.g., Weber, 1997 and Rejesus et al., 2013), farm and farmer characteristics in our sample prove to be poor explanatory variables of climate change beliefs and to be unrelated to farmers' perceived cause (natural or anthropogenic) of climate change.

4.3 Farmer quantitative risk perception elicited via the Exchangeability methods

Table 2 reports summary statistics of the median damage (our measure of agricultural risk perceptions) elicited via the exchangeability method for each crop and peril. For hail risk in 2011, the average perceived median province level damage for apples and grapes is 21.17% and 12.68%, respectively. This difference in perceived damage corresponds with experts' opinions that hail poses a larger threat to apple production in the region than for grapes (CoDiPra, 2013). For apple dieback and powdery mildew the average perceived median province level damage is lower than for hail and equal to 10.47% and 10.12%, respectively. This also matches with experts' opinion that hail poses a more significant risk to apple and grape farmers under current climate conditions compared to other perils (Olesen et al., 2011).

Considering farmer perceptions of future risks, the average median risk perception across farmers for each of the four considered risk types is greater in 2031 than for 2011. For apples and grapes, the median risk due to hail is higher by 5.07% and 5.97% respectively. This difference between 2031 and 2011 hail damage expectations is statistically significant and indicates that farmers perceive a substantial increase in the hail threat in the long-run. This belief is consistent with the emerging concern among climatologists that the gravity of hailstorms in the Province of Trento has increased over the last decades and will continue to increase in the future (Eccel et al., 2012). For apple dieback and grape powdery mildew, farmers also expect an increase in damages in the long-run, but the increase is less substantial (3.16% for powdery mildew and 1.27% for apple dieback) and the latter difference is not significant at standard levels.

**Table 2. Sample average of short-run and long-run risk perceptions (median crop loss)**

Risk Type	Unit of Measure	Obs.	2011	2031	Difference
Hail-Apples	% Province level apple value loss	120	21.17 (13.02)	26.24 (15.98)	5.07***
Hail-Grapes	% Province level grape value loss	75	12.68 (10.01)	18.65 (13.69)	5.97***
Dieback-Apples	% Province level apple trees affected by dieback	120	10.47 (11.64)	11.74 (11.86)	1.27
Powdery Mildew-Grapes	% Province level grape bunches affected by powdery mildew	75	10.12 (10.96)	13.27 (13.38)	3.16***

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[5] Arbuckle et al. (2013b) find that 8% of Midwestern U.S. farmers believe that climate change is caused by human activities.
[6] A 2007-2008 Gallup Poll of Italians found that 65% of the population agreed that climate change is a result of human activities and 76% perceived climate change as a serious personal threat (Pelham, 2009; Pugliese and Ray, 2009).

To further assess the difference in short- vs. long-run hail and disease risks perceived by farmers and the influence of climate change beliefs on these risks, Figure 1 presents a breakdown of results from the exchangeability method experiment based upon climate change beliefs, than means distinguishing between climate change believers (CC) and skeptics/non-believers (NC). Several key results are found. First, comparing 2011 damage expectations between CC and NC, we find only small differences in expectations and none that are statistically significant based on t-tests. This indicates that both climate change believers and non-believers have similar perceptions about the current risks faced by farms in their region. Climate change believers expect damages to increase in the future. For non-believers, only small increases in hail risks are expected and for the two crop diseases, apple dieback and grape powdery mildew, damages are actually expected to decrease slightly. Comparing the difference between 2031 and 2011 damage expectations between CC and NC using unpaired t-tests we find that for apples and grapes the hail damage expectation is significantly different (p-value 0.056 and 0.002, respectively) as well as for apple dieback (p-value 0.088). However, the change in damage expectations is not significantly different for grape powdery mildew.
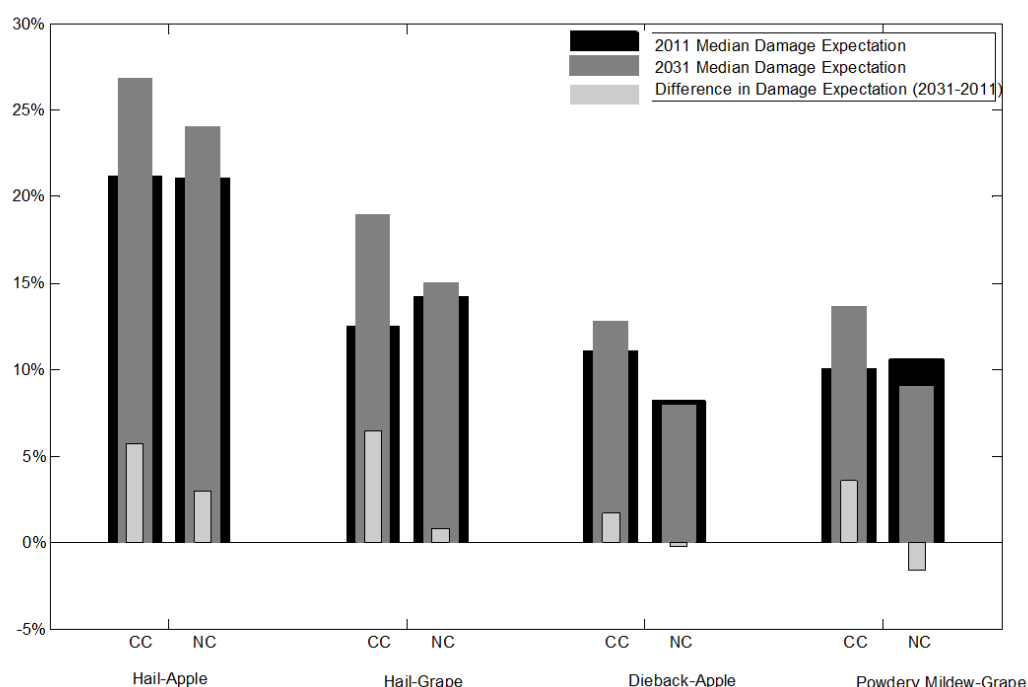
Figure 1. Quantitative agricultural risk perception by climate change beliefs

4.4. Regression analysis of the determinants of risk perceptions

To further assess the factors that affect farmers' perceptions of future hail and crop disease risks and the influence of climate change on these perceptions, in this section we report results from four linear regression models controlling for a variety of factors that could be hypothesized to influence risk perceptions. In each of the models reported in Table 3 the dependent variable is the change in farmers' median province level crop damage between 2011 and 2031 elicited via the exchangeability method. Results are reported for each of the four risk factors considered in the study: Apple Hail, Grape Hail, Apple Dieback, and Grape Powdery Mildew.

In each of the regressions, the first explanatory variable is climate change beliefs. In addition, farmer socio-demographics and farm characteristics that could be hypothesized to influence risk perceptions are included (e.g., age and education). As well, to assess the

potential influence of salient experience with hail and crop disease, a variable is included indicating whether farmers have personally seen recent significant crop damage due to hail or crop diseases on farms in their region. Moreover, to control for potential information effects on risk expectations, four variables are included to capture interactions with local farming cooperatives and outreach efforts by local insurance and extension services. Finally, the number of correct answers in the probabilistic task allows to investigate the effect of probabilistic numeracy (see Table 1 for a description of the explanatory variables).

Regression results reported in Table 3 suggest two important results. In the Apple Hail, Grape Hail, and Apple Dieback models farmers' beliefs in climate change are found to be positive and significant at the 10% level. This result suggests that farmers are indeed considering the negative consequences of a changing environment on adverse weather events and crop diseases when forecasting future farm risks and is consistent with the finding of Arbuckle et al. (2013a) and Safi et al. (2012) who find that risk perceptions are higher among farmers who believe in climate change.

In the powdery mildew regression instead farmers' beliefs in climate change are found not to be significant at standard confidence level indicating that climate change believers and skeptics have similar perceptions of future crop loss risk due to powdery mildew. It is then conceivable that the long experience that winegrowers have accumulated for generations in fighting powdery mildew under varying weather conditions provides a sense of confidence (controllability and manageability) that, as suggested by the managerial literature, tend to reduce risk perceptions (Weber, 2002). In contrast, apple dieback is a relatively new and unknown peril for farmers and researchers themselves are currently investigating how to prevent or control the disease.

Consistently across all four models, we find that farmers who have first-hand experience seeing significant damage to fields in their region from hail, dieback, or powdery mildew expect future crop damages to increase significantly more compared to farmers without such first-hand experience. This finding is consistent with several studies addressing risk perceptions of farmers (Diggs, 1991; Niles et al., 2013) as well as the general population (Akerlof et al., 2013). Interestingly, no similar effect is found for the other information variables included in the model (Sessions & Articles, Co.Di.Pr.A., or the two cooperative variables). These results are consistent with the evidence emerging from a recent review of 82 studies on population risk perceptions of natural hazards by Wachinger et al. (2013) who finds that direct experience exerts a strong effect on risk perception while indirect experience (education, media, and hazard witnesses) has only a minor effect. These results suggest for extension professionals seeking to convey to farmers the potential risks from climate change that "field days", in which farmers visit a farm and gain first-hand on-farm experience with crop damages, best practices, and risk management strategies, might be a more effective approach compared to traditional off-farm information sessions and articles.

Finally, the only other variable found to have significant explanatory power across the four models is farmers score on the probability test. Specifically, we find a positive relationship between farmers probabilistic numeracy and the change in the expectation of future and current crop damage. This adds new evidence to the recent literature investigating the positive relationship between probabilistic numeracy and risk assessment.

Table 3. Linear regression models of the change in risk perceptions between 2011 and 2031

Variable	Farmers' 2031-2011 Median Province Damage Expectations			
	Apple Hail	Grape Hail	Apple Dieback	Grape Powdery Mildew
Climate Change Belief	3.161*	3.802**	2.478*	5.902
	(1.648)	(1.716)	(1.377)	(4.268)
Age	-0.046	-0.036	0.042	-0.077
	(0.100)	(0.074)	(0.088)	(0.095)
Education	0.002	1.236***	-0.130	0.518
	(0.357)	(0.405)	(0.384)	(0.405)
Farm Size	-0.492	-0.168	0.375	-0.464
	(0.341)	(0.316)	(0.250)	(0.311)
Cultivated/Owned	0.012	-0.003	0.020	0.045
	(0.029)	(0.028)	(0.035)	(0.038)
Farming Experience	-0.069	0.149*	0.024	0.086
	(0.094)	(0.085)	(0.084)	(0.081)
Full Time	0.236	-1.213	0.314	-0.403
	(2.067)	(1.767)	(2.398)	(2.266)
Household Size	-0.408	-0.180	0.328	-0.621
	(0.777)	(0.552)	(0.776)	(0.845)
Income	0.941	0.089	0.532	1.782
	(0.737)	(0.759)	(0.684)	(1.237)
Liquidity	0.571	-0.146	-3.957	-3.443*
	(2.238)	(1.638)	(2.411)	(1.964)
Damage Experience [a]	3.480*	2.561*	3.364*	4.085**
	(1.841)	(1.435)	(1.805)	(1.619)
Probability Test Score	1.111*	0.826**	1.039*	1.511***
	(0.655)	(0.373)	(0.620)	(0.504)
Coop Member	-0.685	0.624	-2.248	3.482
	(2.404)	(3.400)	(2.471)	(4.361)
Coop Representative	1.326	-1.952	1.697	1.998
	(1.759)	(1.806)	(1.459)	(2.808)
Co.Di.Pr.A	2.904*	1.645	2.010	0.092
	(1.652)	(1.555)	(1.633)	(2.130)
Sessions & Articles	-0.279	0.581	-0.573*	0.442
	(0.407)	(0.378)	(0.291)	(0.393)
Constant	-0.191	-17.573**	-7.508	-20.695*
	(7.926)	(7.337)	(7.389)	(10.580)
R-Squared	0.159	0.490	0.164	0.348

Note: *, **, *** denote 10%, 5%, and 1% significance levels, respectively. Stdev in parenthesis.
[a] For the Apple Hail and Grape Hail regression this explanatory variable is past experience with hail damage.
  For Apple Dieback and Grape Powdery Mildew this variable is past experience with damage from that peril.

4.5 Comparing qualitative and quantitative risk perceptions

To conclude our analysis of risk perceptions, in this section we provide a brief discussion of farmers' answers to the Likert scale type questions meant to qualitatively elicit risk perceptions. We also compare the qualitative and quantitative measures of risk perceptions.

Table 4 summarizes farmers' answers to the Likert type question asking farmers to assess how climate change will affect the average crop losses due to hail, powdery mildew, or apple dieback. Similarly to the Likert type questions used in previous literature, our questions explicitly mention climate change. The average positive scores ranging from 1.28 to 1.49 suggest that farmers expect a moderate increase in crop losses for each crop and peril. No statistically significant difference is found across crops and perils. To the contrary, the

quantitative measures presented in Table 2 show that essentially no increase in crop losses is expected for apple dieback while an increase in crop losses ranging from 3.16 to 5.97 is expected for the other perils. Borrowing the terminology of Leiserowitz (2006), these results seem to suggest that the qualitative measure of risk perceptions might capture a "holistic measure of concern" pointing to a moderate level of concern. The quantitative measures allow a numeric interpretation of the "moderate" concern.

Table 4. Qualitative changes in expected average damage at the province level in the long-run (2031), Direct question Likert scale (-5 to +5)

Risk Type	Obs.	Mean	StdDev
Hail-Apples	120	1.28	1.86
Hail-Grapes	75	1.49	1.36
Dieback-Apples	120	1.34	1.85
Powdery Mildew-Grapes	75	1.48	1.84

Further dissecting responses by climate change believers (CC) and non-believers (NC) confirms significant differences in expected damages between the two groups. As can be seen in Table 5, compared to non-believers climate change believers expect a larger increase in damage from hail on both apples and grapes (unpaired t-test p-values 0.069 and 0.073, respectively) and from apple dieback (p-value 0.001). Comparing these results with the quantitative measures (Table 2), we can conclude that both question formats, quantitative and qualitative, consistently capture the same statistically significant differences between climate change believers and non-believers.

Table 5. Qualitative changes in expected average damage at the province level in the long-run (2031) distinguishing between climate change believers vs. non-believers

Risk Type	CC Believers	CC Non-Believers	Difference
Hail-Apples	1.43	0.77	0.65*
	(0.20)	(1.43)	
Hail-Grapes	1.55	0.83	0.72*
	(0.17)	(0.31)	
Dieback-Apples	1.59	0.48	1.10***
	(0.20)	(0.25)	
Powdery Mildew-Grapes	1.55	0.67	0.88
	(0.23)	(0.49)	

5. Conclusion

A significant component of the concern surrounding climate change is the potential for negative effects on agricultural productivity and farmer welfare. An important condition for farmers to engage in mitigation or adaptation strategies is that farmers perceive climate-change related agricultural risks. As well, for policy makers to design programs to assist farmers dealing with climate change it is critical not only to understand the impact on agricultural production, but also to understand how and to what extent farmers perceive these impacts and respond to them.

This study contributes to the existing literature investigating farmers' perceptions of agricultural risks brought about by climate change. While previous research has elicited risk perceptions through different types of qualitative scales and has focuses either on the severity of the expected damages or on the probability of occurring, we elicit the median of the

perceived cumulative distribution of crop losses. The elicitation is performed with the exchangeability method, an indirect method to elicit subjective beliefs regarding risk that does not require difficult probability reasoning.

Our empirical evidence provides insights for policy makers and outreach professionals to better assist farmers adapt to changing conditions due to climate change. We find that a significant portion of farmers in our sample are not merely concerned about climate change, but are indeed forecasting increased crop losses for the future. A smaller but significant sample of farmers instead not only is skeptical regarding the climate change phenomena and does not recognize any increase in risk for their operations. Moving forward with farmer assistance programs, the findings of our study provide support for the "segmented approach to outreach with farmers" suggested by Arbuckle et al. (2013b) that takes into account difference in farmers' beliefs about climate change. Whereas some farmers might benefit from general education regarding climate change and their consequences on crop losses, for others effective outreach should focus on assistance with cost-effective methods to control or mitigate risks of which they are already aware. Moreover, given the key role of first-hand experience with past hail and/or pest damages in explaining risk perceptions, "field days" conducted by local extension services might be a more effective approach in increasing farmers' awareness of climate change risks compared to traditional off-farm information sessions and articles.

While we hope that the study provides interesting insights with regard to farmers' ability to foresee agricultural risks related to climate change, several questions remain open. Are farmers' perceptions of risk commensurate with the objective but unknown risks caused by climate change? Are those farmers' who perceive increased risks due to climate change modifying the behavior and engaging in adaptation strategies? Finally, from a methodological point of view, we auspicate that our study will motivate further research addressing the suitability and consistency of the various elicitation methods currently used to study risk perceptions.

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