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ORIGINAL ARTICLE

Does risk preference influence farm level adaptation strategies? – Survey evidence from Denmark

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Abstract

Farmers' decisions to adopt new technology or measures for agricultural production processes are crucial for adapting to climate change. Meanwhile, risk preference has received great attention over the years in agriculture-related studies as it has been identified as a strong driver for agricultural production decisions. However, empirical studies on the relationship between farmers' risk preferences and adaptation choices in response to climate change remain scant. The present study, utilizing data from a farmer survey in Denmark, aims to examine farmer risk attitude and determine to what extent it influences crop choice decisions, such as crop changes, as an important part of farm level adaptation strategies. Applying a logit regression method, our study finds that: (1) the majority of farmers in the survey were identified as risk tolerant; (2) several demographic and socio-economic factors, such as work experience and farmland tenure were significantly related with farmer risk preference; (3) actual adoption of the majority of farm level adaptation strategies through crop changes and management was found to be significantly less likely for risk averse farmers compared to risk tolerant farmers. Therefore, policy development to promote successful adaptation measures in the agricultural sector should take into account farmers' risk preferences. To this end, risk averse farmers may need better targeting strategies. Future studies could further investigate the role of farmers' risk preferences on the adoption of a wider range of climate change adaptation and mitigation measures and technologies.

Keywords risk preference · behaviour · adaptation · climate change · farmer · agriculture · crop choice · crop management

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1 Introduction

The role of risk preferences in decision making has been an important research topic in agriculture-related studies. Risk preferences have been identified as a strong driver for farm management, land use, and agricultural production decisions (Chavas et al., 2010; Adger et al. 2009; Gershon Feder, 1980; and Just and Zilberman 1983). Moreover, agricultural production continuously faces uncertainty and risk, thus risk preference is crucial in determining farmers' risk management decisions and strategies (Just & Just, 2016 and Pennings & Wansink, 2004). The decision-making context includes the adoption of new technology or new techniques for agricultural production processes. Risk preference has been taken into account in models of technology adoption and has been considered an important factor (Liu, 2013 and Feder et al., 1985).

In general, farmer's risk preference has been measured and studied in several countries, for example Sweden (Hansson and Lagerkvist 2012), Norway (Flaten et al. 2005), Italy (Menapace et al. 2013), China (Jianjun et al., 2015), Indonesia (Sarwosri and Mußhoff 2020), Ghana (Asravor 2019), and Uganda (Ihli et al. 2016). While risk preferences are not directly observable and extremely difficult to measure, several methods have been developed to elicit them, such as presenting the participants with risky choices with different expected payoffs and variance (Liu, 2013 and Trujillo-Barrera et al., 2016). The risk elicitation results have shown that farmers tend to be risk averse as opposed to being risk tolerant (Jianjun et al., 2015; Iyer et al., 2020; Hasibuan et al., 2021; Tevenart & Brunette, 2021). Risk preferences have been found to be correlated with demographic and socio-economic characteristics. Jin et al. (2015) have shown that female farmers were more likely to be risk averse compared to male farmers. Jin et al. (2015), Ullah et al. (2015), and Senapati (2020) have found that experienced or older farmers were more likely to be risk averse compared to younger farmers. Meanwhile, farmers with higher incomes were more likely to be risk tolerant (Bar-Shira et al., 1997).

The effect of farmer's risk preference has led to debates on the likelihood of adoption of new technology or techniques in farming. New technology and new techniques have the potential to improve or provide security for farmer's current production process, yet the uncertainty of the outcomes when taking on these new aspects may pose a stumbling block for adoption to farmers. Studies from Liu (2013), Jianjun et al. (2015), and Alemayehu et al. (2018) have shown that farmers considered the adoption of new technology as a risky decision. Farmers that were risk averse would take on adoption of new technology later compared to risk tolerant farmers (Liu, 2013). On the other hand, there are other studies that have argued that risk aversion may foster adoption for new technology and techniques (Wossen et al., 2015; Asravor, 2019; Sarwosri & Mußhoff, 2020). Meraner and Finger (2019) found that greater risk aversion increases the likelihood that farmers focus on on-farm strategies compared to off-farm strategies to reduce risk. Moreover, research has also suggested that adoption of new techniques that would reduce farm production would be more likely to be adopted by risk averse farmers (Baidu-Forson, 1999).

The adoption of new technology or measures is particularly vital in the face of climate change (IPCC, 2007 and Ozor et al., 2011). Crop diversification is one of the important measures for agricultural adaptation to climate change adaptation (Khan et al., 2020 and Matsuura, 2021). Crop diversification provides a more stable productivity of crops and resilience to drought and weather variability (Kiani et al. 2021). Moreover, households that produce more than one crop tend to have a more secure food supply and income (Mango et al. 2018). If farmers are reluctant or decide not to adopt climate change adaptation measures, farmer's future farm revenue may be at risk.

Existing literature has highlighted the opportunities and challenges arising from climate change to agriculture, both qualitatively and quantitatively (Reilly et al. 2003; Fezzi et al. 2015; Hatfield and Prueger 2015; Zhang et al. 2017; Nainggolan et al. 2023). Notably, some studies have identified the potential positive effects of climate change on agriculture in northern European countries, including Denmark (Olesen et al., 2007). However, previous studies have predominantly adopted a macro-level perspective, hence lacking insights into the micro-level, behavioural aspects of agricultural responses to climate change. Moreover, despite the growing interest in investigating the influence of risk preference on the climate change adaptation decisions made by farmers, the empirical evidence remains inconclusive. The present paper fills the knowledge gaps and offers a novel perspective into the behavioural dimension of agricultural adaptation to climate change by empirically examining the relationship between risk preference and actual farm level adaptation against climate change.

The overarching aim of the present paper is two-fold. Firstly, we characterize farmers' risk preferences and assess to what extent these are related to farm and farmers' characteristics. Secondly, we examine to what extent farmers' risk preferences influence farm level adaptation strategies with a focus on crop changes and management that farmers have already implemented on their farm. The key scientific contribution of the present paper is therefore to provide empirical evidence substantiating the relationship between farmers' risk preferences and their actual farm level adaptation. Understanding how risk preference and other underlying factors drive adoption of climate change adaptation measures is important to inform policies to promote successful adaptation measures in the agricultural sector and evaluate the need to better target different groups of farmers.

The structure of the paper is as follows. Section 2 provides a brief overview of the Danish context of climate change and agricultural land use. Section 3 describes the data and methodological approaches utilized in the present study to elicit farmer risk preference and to assess the relationship between risk preference and farmers' adoption of climate change adaptation measures. Section 4 presents and discusses the findings of the present research. Finally, Section 5 concludes the study and identifies future research directions.

2 Climate, climate change and agricultural land use in Denmark

According to World Bank (2021), Denmark's climate is temperate with an even distribution of precipitation throughout the year. The country experiences an average annual temperature of 8.3°C, which can vary between below 6°C to 10°C. January and February are the coldest months, with an average of around 1°C, while July and August are the warmest months with an average of around 16.5°C (1981-2010); 17°C (2006-2015). The warmest year on record was 2014, while the coldest was in 1879. Precipitation varies widely between years and regions, with an average of 746 mm (1981-2010 level); 792 mm (2006-2015 level) annually. The wettest period typically lasts from June to January, while the driest period is from February to May. In winter, precipitation may fall as snow.

As described in Olsen et al. (2022), Denmark has witnessed a greater rise in temperature than the global average due to a 1.4 to 1.7 times increase in land temperatures compared to ocean temperatures over the past five decades. Since 1980, there has been a consistent increase of about 0.5°C per decade, resulting in a 1.0°C difference in mean temperature between the periods of 1961-1990 and 1991-2020. Year-to-year temperature variability has also increased, with winter variability decreasing due to less snow cover. The growing season has increased by 18 days, allowing for earlier sowing and crop development. Precipitation has increased by an average of 15 mm per decade, and the number of hours of sunshine has increased year-round due to reduced atmospheric pollution by aerosols.

As cited in Olsen et al. (2022), based on the Danish Climate Atlas (Thejll et al. 2021), climate change projections under a medium scenario for greenhouse gas emissions (RCP4.5) suggest a temperature increase of 0.34°C per decade up to 2050, with a larger increase in the projected lowest annual temperature than in the highest temperature. The length of the growing season is projected to increase by 6.5 days per decade, with a significant decrease in frost days. Median value of precipitation is projected to increase by 10 mm per decade by 2030 and a further increase of 4 mm per decade by 2060, but there are large variations between different models in the projected changes in precipitation. No significant changes in solar radiation are expected.

The impact of climate change to agriculture in Denmark is of great importance as the sector encompasses approximately two-thirds of the country's land area. Climate change is expected to be beneficial for crop production in Denmark due to rising temperature, CO2 concentrations, and longer growing seasons (Ministry of Environment of Denmark / Environmental Protection Agency 2023). However, cultivation responses to changing climate differ between crops (Olsen et al. 2022). Besides, the potential benefits could be hampered by various factors, for example, increased costs for fertilizer and pesticides as plant diseases and pests are expected to intensify due to climate change (Olsen et al. 2022; Ministry of Environment of Denmark / Environmental Protection Agency 2023). An integral part of agricultural adaptation to climate change in Denmark includes the development of new cropping systems and breeding of varieties with better tolerance to extreme conditions, which are expected to increase yields and reduce the environmental footprint in plant production (Olsen et al. 2022).

Findings from an econometric model indicate that climate change is expected to alter agricultural land use patterns in the Nordic region where Denmark is expected to experience the most pronounced shifts (Nainggolan et al. 2023). Denmark's agricultural sector is expected to experience a significant reduction in the share of cereal land use, with corresponding increases in other crops. Farmers are likely to adapt to future climate change by reallocating arable lands currently dedicated to cereal production. Meanwhile, Zhao et al. (2022) reported that observed adaptation strategies to climate change in northern Europe have already included changes in the timing of field operations as well as the introduction of new crops and cultivars, in response to a longer growing season and decreased low-temperature stress.

Nainggolan et al. (2023) further highlights that two potential reasons for Denmark's more significant changes, compared to other Nordic countries, are its warmer baseline climate and greater potential for crop reallocation, although uncertainties exist for the agriculture land use shift projections under high-end warming scenarios. The projections in their study assume that the total agricultural area and relative prices will remain at their current baseline values. The authors also highlight that to accurately estimate the relationship between climate and land use, it is essential to consider all variables that affect land use changes including crop price development and agricultural and environmental policy direction, which were not taken into account in the analysis. The recent subsidy offered by the Danish Government to take carbon-rich lowland soils out of production is a relevant example of policy development (Danish Environmental Agency 2022).

All in all, climate change will present both advantages and challenges to Danish agriculture. Crop choices and cultivation practices will have to respond to both aspects. Adaptation to both favourable and unfavourable impacts of climate change will be crucial for the future of Danish agriculture. At the same time, it is expected to mitigate the sector's emissions and deliver multiple agroecosystem services beyond crop production.

3 Methods

3.1 Data Collection

The data utilized in the study was collected through an online survey administered by the Aspecto Market Research & Consultancy between April and May of 2014. The survey development process and its design overview as well as the farming contexts of the target respondents have been described in Woods et al. (2017). The survey was distributed to 2937 farmers through a Danish national farmer panel and the final number of responses was 1053. The response rate of 36% is relatively low but considered not uncommon within farmers surveys, as highlighted in Woods et al. (2017). The focus of the present paper is to evaluate farmer risk preferences and to examine the relation with farm level adaptation reality.

To elicit farmers' risk preferences, our study adapts the hypothetical income gamble method (see Barsky et al. (1997) and Anderson & Mellor (2009)). In this approach respondents are typically presented with a series of questions that provide two scenarios regarding their prospective annual income earning activity; option 1 entails a job with a certain level of guaranteed income, while option 2 presents a job with a higher income but with a higher level of risk (the income was based on probabilities). If respondents chose the non-risky option in the first scenario, they would be given another question representing a scenario with a much lower risk. On the contrary, respondents that chose the risky option in the first instance would then be presented with another scenario entailing a higher risk. In Anderson & Mellor (2009), this process was administered as a triple bounded design. Each risky choice provides a different expected payoffs and variance which allows the elicitation of degrees of risk preference (Liu, 2013 and Trujillo-Barrera et al., 2016). Moreover, the framing of the hypothetical income gamble's questions removes status quo bias by presenting the respondents with a choice between two new jobs, instead of between the respondent's current job and new job.

However, as indicated earlier, our survey employed a simplified version of the hypothetical income gamble due to two primary reasons: (1) the survey was administered online and (2) we did not want to over exhaust the respondents as the farmer risk elicitation exercise was part of a larger survey. In our adapted approach, respondents were all presented with the same set of three questions, where each question allowed respondents to choose either safe or risky option or "don't know". The set of the risk preference questions begins with a high-risk choice and the degree of riskiness of the risky option presented reduced as the series of questions continued. The risky options in our questionnaire were formulated as follows: (Scenario 1) 50% probability of doubling income and 50% probability of reducing income by 33%, (Scenario 2) 50% probability of doubling income and 50% probability of reducing income by 25%, and (Scenario 3) 50% of doubling income and 50% of reducing income by 10%.

Finally, the survey also gathered data on whether the respondents had implemented any farm level adaptations with a focus on crop changes and diversification. Furthermore, data on farmers' socio-demographic characteristics and features of their farm production and business were also collected.

3.2 Data Analysis

3.2.1 Characterizing farmers' risk preferences

In the present study, to characterize farmers' risk preferences, we adapted the approach of hypothetical income gamble (Anderson & Mellor, 2009). As elaborated earlier in section 3.1, the hypothetical income gamble is an approach where respondents are asked a series of two income choices in which one choice is a guaranteed payoff (non-risky) and the other choice is a risky payoff (Schubert et al., 1999; Abdellaoui et al., 2011; Arena et al., 2015; Drichoutis & Lusk, 2016). The non-risky choice's value is held constant, while the risky choice decreases in its degree of riskiness. A respondent's degree of risk preference will be determined by the combination of choices selected by the respondent.

In the present study, our adapted version of the hypothetical income gamble consists of three questions in which the degree of riskiness of the risky option reduces as the series of questions continue. Accordingly, we adapted the algorithm for characterizing farmers' risk preferences in the present study (Fig. 1). Following this algorithm, we identify four degrees of risk preferences. We begin by characterizing the risk preference of those respondents who choose a risky option in the first scenario. Here consistent respondents are expected to always opt for risky option in the subsequent two scenarios. In this group, all the respondents that consistently choose the risky choice are categorized as "high risk tolerant". Next, we examine respondents that initially choose the non-risky option but then switch to the risky option for the other two scenarios. Respondents that follow this path are considered "medium risk tolerant". Meanwhile, respondents that choose the non-risky option in the first two scenarios and then choose the risky option in the last scenario are considered "low risk tolerant". Another group of respondents comprises of those who choose non-risky option in all the three questions; these respondents are considered "high risk averse".

As mentioned earlier, four degrees of risk preference were identified. However, to simplify our further analysis, we then classify respondents into two groups: risk averse and risk tolerant. Moreover, in the risk characterization process, respondents expressing "don't know" responses to all the three risk preference elicitation scenarios are considered "fully don't know" or "indecisive". Other combinations of responses are deemed inconsistent. These "fully don't know" and inconsistent responses, corresponding to 283 respondents, were excluded from the sample in our further analysis (Fig. 1).

3.2.2 Eliciting determinants of risk preference

After identifying the risk preference of farmers (section 3.2.1), we proceed with analyzing the different factors that may explain farmers' risk preferences. Here we utilize the logit model as the dependent variable, risk preference, is a binary variable taking a value of 0 for risk-taker and 1 for risk averse. The focus of our analysis is to examine to what extent farmer's risk preference is explained by a range of farmer's demographic and socio-economic variables (Table 1).

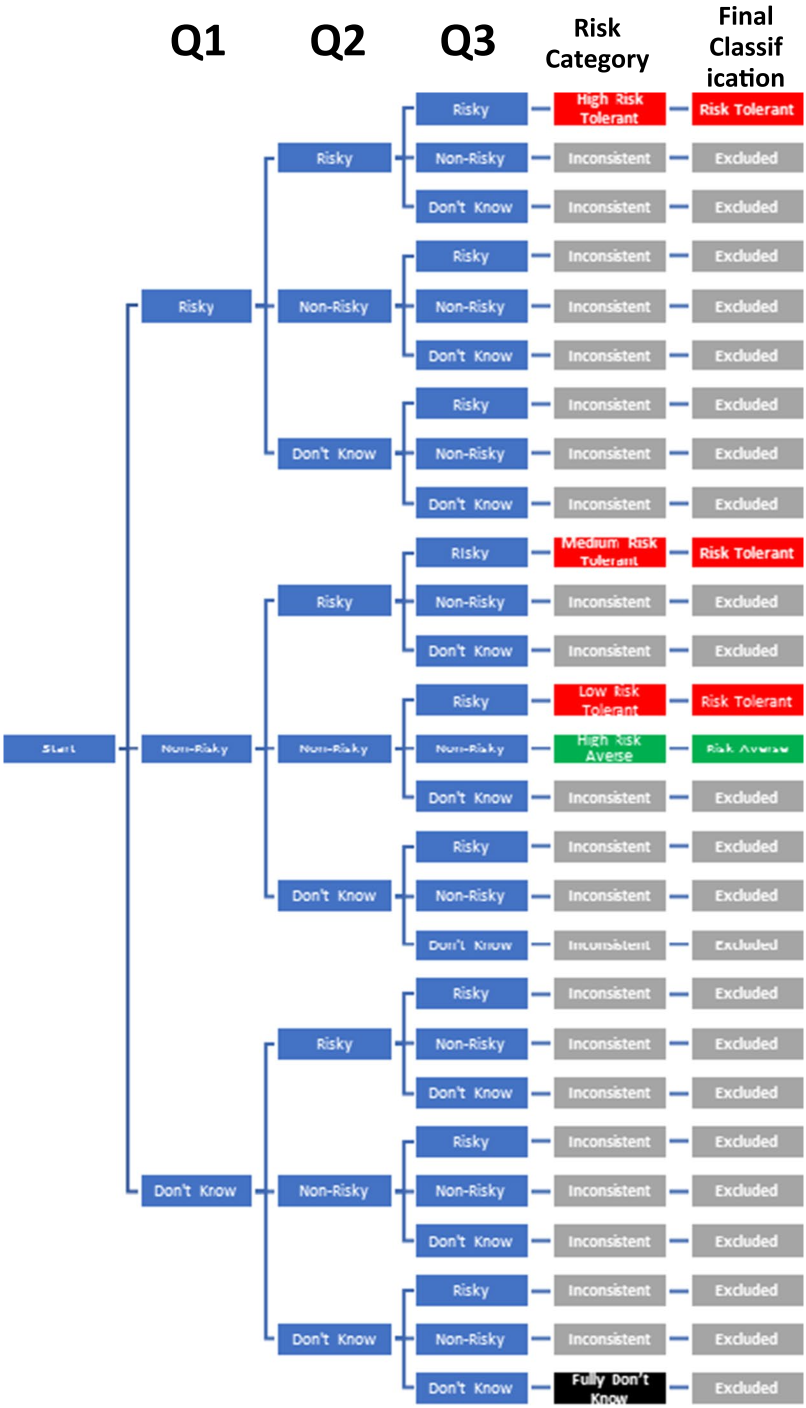

Fig. 1 Risk preference characterization tree for a customized hypothetical income gamble approach

Table 1 List of variables

Variables	Description (values)
Ceasing the cultivation of one or more crops permanently	Farmer has taken on adaptation measure of stopping to grow one or more crops permanently (Dummy, 1 = Yes; 0 = No)
Introducing one or more new crops permanently	Farmer has taken on adaptation measure of introducing one or more crops permanently (Dummy, 1 = Yes; 0 = No)
Introducing one or more new crops as a test	Farmer has taken on adaptation measure of introducing one or more crops as a test (Dummy, 1 = Yes; 0 = No)
Making other changes to the crop choice/management	Farmer has taken on adaptation measure of making other changes to the crop choice/management (Dummy, 1 = Yes; 0 = No)
Risk preference	Farmer's risk preference based on Hypothetical Income Gamble categorization (Dummy, 1 = Risk Averse; 0 = Risk Tolerant)
Gender	Farmer's sex (Dummy, 1 = Male; 0 = Female)
Farm work experience	Farmer's number of years working at the farm (Years)
Full time farmer	Farming as a full time employment for the farmer (Dummy, 1 = True; 0 = False)
Organic only farmer	Nature of farm's production is fully organic (Dummy, 1 = True; 0 = False)
Organic and non-organic farmer	Nature of farm's production includes both organic and non-organic (Dummy, 1 = True; 0 = False)
Agriculture related education	Farmer received education pertaining to agronomy, agricultural technician, green certificate, or others (Dummy, 1 = True; 0 = False)
Farmer as land owner	Farmer is the owner of the farm land (Dummy, 1 = True; 0 = False)
Total land size	Total farm land size (Hectares)
Size of land in rotation	Total farm land size under rotation (Hectares)
Number of farm labours	Number of full-time employees working in farm (People)
Gross farm income	Yearly gross income from farming activities (total sales minus variable costs; therefore, not including rent, salary, tax, etc) (million kroner)

Farmer's demography consists of the farmer's gender, work experience in farming, farming full time status, farm ownership, and education. The farm socio-economic variables consist of total land size, number of farm labors, and farm income. We also add the marginal effects of the regression as the values of the coefficients from the logit model do not allow direct interpretation as is the case of linear regression. The logit model of risk preference in the present study follows:

$$RiskPreference_i = \sum\nolimits_{j=1}^{J} \alpha_j \Delta FarmerDemo_{ji} + \sum\nolimits_{l=1}^{L} \alpha_l SocioEcon_{li} + e_i \quad (1)$$

3.2.3 Assessing the relation between risk preference and farm level adaptation choice

We conclude our analysis by examining whether income risk preference of farmers have any bearing on their decision to have implemented a selection of farm level climate change adaptation measures. Our study illustrates this by examining four climate change adaptation measures that involve crop management: (1) ceasing the cultivation of one or more crops permanently; (2) introducing one or more new crops permanently; (3) introducing one or more new crops as a test; and (4) making other changes to the crop choice/management (see Table 1). Analytically, we adopted a logit model as the dependent variable is a binary variable taking value of 1 for taking on the climate change adaptation measure and 0 for not taking on the measure[1]. We also control for a number of farmer's demographic and socio-economic variables (see Table 1). Farmer's demography consists of the farmer's gender, work experience in farming, full time status, farm ownership, and education. Meanwhile, the socio-economic variables consist of size of land in rotation, number of farm labors, and farm income. We provide the marginal effects of the regression as the values of the coefficients from the logit model are not readily interpretable as is the case of linear regression. The model is specified as follows:

$$AdaptationMeasure_{ji} = \beta_1 RiskPreference_i + \sum_{l=1}^{L} \beta_l \Delta FarmerDemo_{li} + \sum_{m=1}^{M} \beta_m SocioEcon_{mi} + \in_i \tag{2}$$

4 Results and Discussion

4.1 Overview of the farmers' characteristics and responses

Demography-wise, the farmers in the survey were mostly males (94%), purely non-organic farmers (93%), had a form of agriculture related education (80%) (Table 2). Full time farmers made up 60% of our sample. Moreover, on average, the farmers had a work experience of 27 years. Farmers in our survey predominantly own the land (97%). On average, these farmers own 143 hectares of land in rotation with 1.5 full time employees working on the farm land. These farmers also earned 2.95 million DKK in gross farm income per year on average. Our sample is considerably representative; however, as discussed in Woods et al. (2-17), the large farms are overrepresented due to the disproportionate number of larger farms in the Aspecto farmer panel. Ninety four percent of the farmers in our sample were 40 or above which is only slightly higher than Statistics Denmark's calculation in 2013 (93%).

The proportion of farmers in our sample that have actually implemented farm level adaptation related to crop choice ranges from 15% to 35% depending on the adaptation measure. Introduction of one or more new crops permanently appeared to be the most popular adaptation (35%), followed by stopping to grow one or more crops permanently (32%). Meanwhile, making other changes to the crop choice/management was the least popular adaptation measure taken on by farmers (15%). Regarding these other changes, farmers' responses are diverse, with some farmers opting to cultivate more winter crops and others favoring spring crops. Similarly, while some farmers allocated more land to grass production, others reduced their grass cultivation. Some farmers stopped cultivating beetroot while others introduced it to their land. A number of farmers reported conversion to organic farming. Some farmers shifted from roughage or fodder production to growing cash crops. Interestingly, while some farmers reported introducing or expanding their maize cultivation, none reported decreasing or discontinuing maize cultivation. However,

[1] A number of respondents provided "don't know" responses to the question on whether they have adopted an adaptation measure; consequently these respondents were excluded from the analysis.

Table 2 Descriptive Statistics of Sample ($n = 609$)

Variable	Category	Statistics
Ceasing the cultivation of one or more crops permanently (1 = Yes; 0 = No)	Yes (%)	31.95
	No (%)	68.05
Introducing one or more new crops permanently (1 = Yes; 0 = No)	Yes (%)	35.06
	No (%)	64.94
Introducing one or more new crops as a test (1 = Yes; 0 = No)	Yes (%)	26.04
	No (%)	73.96
Making other changes to the crop choice/management (1 = Yes; 0 = No)	Yes (%)	14.94
	No (%)	85.06
Risk preference (1 = Risk Averse; 0 = Risk Tolerant)	Risk Averse (%)	22.19
	Risk Tolerant (%)	77.81
Gender (1 = Male; 0 = Female)	Male (%)	94.38
	Female (%)	5.62
Farm work experience (Years)	Min-Max (Mean)	0 – 72 (26.89)
Full time farmer (1 = True; 0 = False)	True (%)	59.76
	False (%)	40.24
Organic only farmer (1 = True; 0 = False)	True (%)	6.21
	False (%)	93.79
Organic and non-organic farmer (1 = True; 0 = False)	True (%)	1.04
	False (%)	98.96
Farmer has agriculture related education (1 = True; 0 = False)	True (%)	80.47
	False (%)	19.53
Farmer owns land (1 = True; 0 = False)	True (%)	97.34
	False (%)	2.66
Size of land in rotation (Hectares)	Min-Max (Mean)	0 – 1095 (143.93)
Number of farm labors (People)	Min-Max (Mean)	0 – 36 (1.47)
Farm income (Million DKK)	Min-Max (Mean)	0.25 - 38.75 (2.95)

For the presentation here, the descriptive statistics are based on the sample of 676 farmers which contain complete responses to questions on farmers' implementation of farm level adaptation measures through crop changes and management. Descriptive statistics for the sample used in the risk preference analysis (710 respondents) can be found in Table 6 Appendix.

all in all, the available responses were insufficient for an analysis to quantitatively discern overarching patterns or dominant changes.

Our survey data indicate that the majority of the farmers in our sample are risk tolerant. Only 22% of the farmers in the study were found to be risk averse. This distribution of risk preference is quite different from other studies which mostly identify farmers as risk averse individuals (Jianjun et al., 2015; Iyer et al., 2020; Hasibuan et al., 2021; Tevenart & Brunette, 2021). However, there have been other studies finding a majority of the farmers surveyed to be risk tolerant/risk seeking individuals (Smidts, 1997; Pennings & Wansink, 2004). It is also important to note that the concept of risk perception itself is a relative concept. Therefore, it is likely to be context and circumstance specific which would lead to differing risk preference distributions (Iyer et al. 2020).

Table 3 Farmers' Risk Preference Categories Based on the Hypothetical Income Gamble Risk Elicitation Results (n = 1053)

Risk Categorization	Freq	%
Category 1 - High risk tolerant	421	39.98
Category 2 - Medium risk tolerant	39	3.70
Category 3 - Low risk tolerant	133	12.63
Category 4 - High risk averse	177	16.81
Inconsistent	183	17.38
Indecisive	100	9.50
Total	1053	

4.2 Risk preference and farmer characteristics

In general, from the hypothetical income gamble approach, we find that our samples were in majority identified as risk tolerant[2] (Table 3). From our initial sample (n = 1053), farmers were mostly found as high risk tolerant (39.98%). Moreover, the proportion of medium and low-risk tolerant farmers were respectively 3.7% and 12.63%. In total, the proportion of risk tolerant farmers were 56.32% while the proportion of risk averse farmers was 16.81%. The remaining 26.88%, which were then dropped from the analysis, comprised of farmers who gave inconsistent responses and those expressing "don't know" to all the risk preference questions; hence identified as being indecisive. After taking out the aforementioned portion of the sample, in the final dataset for further analysis, the proportion of risk tolerant farmers was 77.75% with the remaining farmers being risk averse.

The analysis results highlight several farmer characteristics that significantly drive risk preference of farmers (Table 4). Demography-wise, gender and farm work experience are found to be statistically significant determinants. Male farmers were less likely to be identified as risk averse compared to female farmers; however, it is important to note that female farmers only made up around 5% of the sample. Nonetheless, this finding is in line with Nielsen et al. (2013) and Jianjun et al. (2015) that found female farmers were more likely to be risk averse compared to male farmers. To such a situation, Croson and Gneezy (2009) offers plausible explanations in that females are more prone to express emotional reactions, particularly fear, in response to negative outcomes, while males tend to exhibit overconfidence in the face of uncertainty. Furthermore, females are more inclined to construe risky situations as threatening, whereas males tend to construe risky situations as challenging. Work experience had a positive effect on the probability of being risk averse. An increase of 1 year in work experience would increase the probability of the farmer being risk averse by 0.4%. Similar to Nielsen et al. (2013) and Senapati (2020) older and experienced farmers were more likely to be risk averse. Younger farmers are more likely and willing to take on risk compared to older farmers (Ullah et al. 2015).

With regards to socio-economic factors, farmland ownership, total land size and number of farm labors significantly determined probability of risk preference. Farmers that owned their farmland had a lower probability of 19.9% of being risk averse compared to those who did not own their land. Moreover, the number of farm labors had a negative effect on the probability of being risk averse. An increase of one labor working in the farm would

[2] Descriptive statistics utilized in the regression can be seen in Appendix Table 6

Table 4 Risk Preference Regression Results

	(1)	(2)
	Logit	Marginal Effect
VARIABLES	Farmer's Risk Preference (Risk Averse = 1; Risk Tolerant = 0)	Farmer's Risk Preference (Risk Averse = 1; Risk Tolerant = 0)
Sex (1 = Male; 0 = Female)	-0.645*	-0.104*
	(0.374)	(0.0597)
Farm work experience (Years)	0.0307***	0.00493***
	(0.00827)	(0.00129)
Full time farmer (1 = True; 0 = False)	-0.263	-0.0423
	(0.232)	(0.0371)
Farmer has agriculture related education (1 = True; 0 = False)	0.0114	0.00183
	(0.246)	(0.0396)
Farmer owns land (1 = True; 0 = False)	-1.292**	-0.208**
	(0.544)	(0.0864)
Total land size (Hectares)	-0.00154*	-0.000248*
	(0.000900)	(0.000144)
Number of farm labors (People)	-0.148*	-0.0238*
	(0.0804)	(0.0129)
Farm income (Million DKK)	0.0148	0.00239
	(0.0231)	(0.00372)
Constant	0.205	
	(0.625)	
Observations	710	710

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

reduce the probability of the farmer being risk averse by 2.2%. In the same vein, farm land size reduced the likelihood of being risk averse. An increase of one hectare of total land size would reduce the probability of the farmer being risk averse by 0.02%. A previous study has shown that farmers that were richer and had more assets were less likely to be risk averse (Bar-Shira et al. 1997). Another study found that farmers who owned larger farmlands were able to spread the risk of technology failures through allocating portions of their land for the new technology, which would be difficult for farmers who have small farmland (Mariano et al. 2012). However, there have also been suggestions that farmers with bigger land are more risk averse (Senapati 2020).

4.3 Farm level adaptation strategies and risk preference

Now, we are reporting the results from analyzing whether there is a link between risk preference and farmers having implemented farm level adaptation strategies. The present study focuses on crop changes and management which include four measures where farmers: 1) stopped growing one or more crops permanently; (2) introduced one or more new crops permanently; (3) introduced one or more new crops as a test; and (4) made other changes to the crop choice/management. Our results show that in general risk averse farmers are less likely to have implemented adaptation measures compared to risk tolerant farmers (see Table 5). This suggests that risk averse farmers prefer to carry out business as usual. From the four adaptation measures analyzed in the present study, risk preference statistically significantly contributed to the propensity of farmers to take on one of these three measures: (1) ceasing the cultivation of one or more crops permanently; (2) introducing one or more new crops as a trial; and (3) making other changes to the crop choice/management. Meanwhile, adaptation measure through permanent introduction of one or more new crops was not found statistically significant although the sign was consistent with the other measures.

The results show that risk averse farmers were less likely to have implemented the aforementioned adaptation measures compared to farmers that were risk tolerant. Risk averse farmers had a 9.4% lower probability of stopping to grow one or more crops permanently compared to risk tolerant farmers (see Table 7 in Appendix for marginal effects). Risk averse farmers also had a 13.6% lower probability of introducing one or more crops as a test (trial) compared to risk tolerant farmers. Moreover, the risk averse farmers had a 10.6% lower probability of making other changes on their crop portfolio compared to risk tolerant farmers.

As studies that provide quantitative evaluation on the relation between farmer risk attitude and actual farm level adaptation in the context of climate change remain limited, here we look into more generic studies to gain comparative insights. Overall, studies on how risk preference affects adoption of adaptation measures and/or new technology have shown mixed results. Our study has been in line with studies such as Liu (2013), Jianjun et al. (2015), and Alemayehu et al. (2018) which show that adoption of adaptation measures or new technology is considered a risky decision. Liu (2013) has shown that risk averse farmers are more hesitant to take on a new technology, in the context where cotton farmers in China took longer to adopt genetically modified Bacillus thuringiensis (Bt) cotton despite research showing the new cotton provided higher yields and resistance to pests. Alemayehu et al. (2018) has also found that risk aversion negatively affects adoption of high yield variant (HYV) seeds as farmers considered adoption of HYVs as risk-increasing activities. However, other studies have also argued that risk aversion expedites the adoption of new techniques or technology as they may provide solutions to curbing the agriculture risks (Wossen et al., 2015; Asravor, 2019; Sarwosri & Mußhoff, 2020). The relationship is not always that straightforward and is also influenced by the understanding of how farmers perceive the risks of a new measure (Alemayehu et al. 2018). For example, Baidu-Forson (1999) has shown that, in general, risk averse farmers tended to not adopt new technology. However, if the new technologies were able to provide evidence of risk reduction characteristics it would eventually incentivize farmers to adopt those technologies. Moreover, Tevenart & Brunette (2021) has shown that a technology such as the application of nitrogen fertilizers is not perceived as a risk-decreasing inputs which became a barrier of adoption of these practices for risk averse farmers. Still, the findings from the present study highlights that risk averse farmers tend to follow business as usual and hence are not as adaptable as their risk tolerant counterparts.

Our results also identify several farmer characteristics being statistically significant determinants of farmers' likelihood to adapt through crop choice alteration. Demography-wise, farm work experience and being full-time farmers are found to be statistically significant factors. A farmer's work experience increased his/her probability of taking all the three adaptation measures where an increase of one year experience would increase the probability by 0.3 to 0.7% depending on the adaptation measure. This is similar to findings of Ihli et al. (2016) which found experienced farmers in Uganda were more likely to take on new technology, such as certification adoption. Adesina and Baidu-Forson (1995) provide a plausible explanation:

Table 5 Farm Level Climate Change Adaptation Measure Regression

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as trial	Other changes in crop choice/management	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as trial	Other changes in crop choice/management
Farmer's risk preference (1 = Risk Averse; 0 = Risk Tolerant)	-0.410**	-0.214	-0.818***	-0.851***	-0.465**	-0.138	-0.779***	-0.876***
	(0.209)	(0.198)	(0.246)	(0.323)	(0.222)	(0.208)	(0.260)	(0.334)
Sex (1 = Male; 0 = Female)					-0.457	0.177	0.784	1.006
					(0.386)	(0.397)	(0.520)	(0.763)
Farm work experience (Years)					0.0368***	0.0188**	0.0172**	0.0284***
					(0.00781)	(0.00742)	(0.00825)	(0.00988)
Full time farmer (1 = True; 0 = False)					0.599***	0.458**	-0.0613	-0.317
					(0.216)	(0.209)	(0.231)	(0.278)
Organic only farmer (1 = True; 0 = False)					0.184	0.0293	1.751***	-0.0718
					(0.350)	(0.344)	(0.353)	(0.469)
Organic and non-organic farmer (1 = True; 0 = False)					1.014	0.850	0.717	0.582
					(0.795)	(0.802)	(0.822)	(0.903)

Table 5 (continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as trial	Other changes in crop choice/management	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as trial	Other changes in crop choice/management
Farmer has agriculture related education (1 = True; 0 = False)					0.0913	-0.169	0.0876	-0.173
					(0.254)	(0.240)	(0.271)	(0.316)
Farmer owns land (1 = True; 0 = False)					0.629	0.920	-0.139	0.371
					(0.659)	(0.658)	(0.607)	(0.827)
Size of land in rotation (Hectares)					0.000325	0.00138**	0.00225***	0.00220***
					(0.000661)	(0.000650)	(0.000707)	(0.000773)
Number of farm labors (People)					0.00617	-0.0134	-0.0136	0.0388
					(0.0433)	(0.0413)	(0.0498)	(0.0553)
Farm income (Million Danish Kroner)					-0.0146	-0.00331	-0.0338	-0.0404
					(0.0206)	(0.0193)	(0.0228)	(0.0308)
Constant	-0.670***	-0.570***	-0.891***	-1.591***	-2.351***	-2.501***	-2.383***	-3.685***
	(0.0921)	(0.0908)	(0.0960)	(0.116)	(0.742)	(0.749)	(0.780)	(1.096)
Observations	676	676	676	676	676	676	676	676

experienced farmers may have better ability to assess the characteristics of technology than less experienced farmers, thus likely to adopt new technology. Moreover, when older farmers are able to overcome information barrier of new technologies, they are able to quickly adopt the technologies as they have higher resource endowment (hence less financial constraints) than younger or new farmers (Simtowe et al. 2016). However, there have been studies that have shown that experienced or older farmers being more resistant to new technology or adaptation measures (Jin et al., 2015; Khan et al., 2020). The present study found that full time farmers were also more likely to take on adaptation measures compared to part-time farmers. This finding was consistent with Morgan et al. (2015) and Pagliacci et al. (2020). The adoption of new technologies or practices is likely to be more prevalent amongst full-time farmers especially when the implementation and maintenance of these technologies demand specific skills and consistent commitment and engagement in farm activities (Pagliacci et al. 2020).

The size of farmland in rotation and land ownership are statistically significant socio-economic determinants. The total land size in rotation had a positive effect on the probability of taking on adaptation measures. An increase of one hectare of total land in rotation would increase the probability of the farmer taking on adaptation measures by approximately 0.03%. Farmland size is an important factor to encourage adoption of risk management strategy, including adoption of adaptation measures (Asravor 2019). Farmers with bigger lands were able to spread the risk of technology failure to a certain portion of the land (Mariano et al. 2012). Moreover, farmers with bigger land tend to have more diverse crops (Bezabih and Sarr 2012).

5 Conclusions

Using empirical data from a nation-wide farmer survey in Denmark, the present study characterizes farmers' risk preferences and the determinants, and analyses the relationship between risk preferences and farm level adaptation through crop switch and management that have been adopted by farmers. We found that the majority of farmers in the present study were identified as risk tolerant (77.8%). The study showed that there are several demographic and socio-economic factors that are significantly associated with farmer risk preference. Gender and work experience significantly affected risk preference, where males were less likely to be risk averse compared to females and work experience increased likelihood of risk averseness. In terms of socio-economic factors, farmland ownership, total land size and the number of farm labors significantly affected probability of risk preference. Furthermore, the study also showed that the adoption of the majority of farm level adaptation through crop changes and management were significantly related to risk preference. Risk averse farmers were less likely to take on the adaptation measures compared to risk tolerant farmers. In addition, farmers' socioeconomic and demographic characteristics were also significantly associated to farmers' likelihood to adapt through crop choice alteration. Work experience, full-time farmer status, size of farmland in rotation, and land ownership affected the likelihood to adopt climate change adaptation measures.

The present study offers further empirical insights into the scientific domain of farmer risk preference. Nevertheless, a few limitations of the study are acknowledged. First, with the available data where risk preference elicitation in the survey question involved only limited choices, consequently the assessment of the risk preference becomes limited. Providing more choices in the hypothetical income gamble for risk preference elicitation would have made it possible to capture a greater degree of risk preference spectrum;

hence making it possible to capture a wider array of risk averse preference. Second, the present study focused only on a selection of adaptation strategies related to crop choice and management. Future studies should investigate a broader range of farm level adaptation strategies. Adoption of new technology, other techniques, and investing in climate change related insurance are among the alternative actions to adapt to climate change (Jin et al., 2015). Third, with the available data, several variables could not be included in the present analysis albeit potentially relevant for farm level adaptation, such as off-farm employment or income (cf. Danso-Abbeam et al. 2021) and biophysical aspects (e.g. soil quality and water availability) of the farm (cf. Asprilla Echeverría 2022). Future studies should further expand the risk elicitation method and incorporate other measures beyond crop choice alteration for climate change adaptation. Moreover, incorporating a deep analysis on climate change risk perception would also generate better understanding on farmers' likelihood to adopt farm-level climate change adaptation measures.

Despite the aforementioned caveats, the present study highlights the importance of assessing farmers' risk preferences with a clear policy relevance. Findings from the present study indicate that policies on adaptation measures as part of risk management strategies at farm level must take farmers' risk preferences into consideration. The present study suggests that risk averse farmers may need better targeting. To this end, additional support through provision of information on how adaptation measures curb risk of climate change may prove necessary for convincing risk averse farmers to take on farm level adaptation measures. When risk averse farmers are exposed to new methods and are convinced that these methods do not pose risks and/or have the capacity to reduce risk (such as climate change risk) the likelihood for implementing farm level adaptation is likely to be improved.

Appendix

Table 6 Descriptive Statistics of Risk Preference Regression ($n = 710$)

Variables	Category	Statistics
Risk preference (1 = Risk Averse; 0 = Risk Tolerant)	Risk Averse (%)	22.25
	Risk Tolerant (%)	77.75
Sex (1 = Male; 0 = Female)	Male (%)	94.37
	Female (%)	5.63
Farm work experience (Years)	Min-Max (Mean)	0 – 72 (26.96)
Full time farmer (1 = True; 0 = False)	True (%)	60.14
	False (%)	39.86
Farmer has agriculture related education (1 = True; 0 = False)	True (%)	80.42
	False (%)	19.58
Farmer owns land (1 = True; 0 = False)	True (%)	97.32
	False (%)	2.68
Total land size (Hectares)	Min-Max (Mean)	1 – 1313 (157.24)
Number of farm labors (People)	Min-Max (Mean)	0 – 36 (1.45)
Farm income (Million Danish Kroner)	Min-Max (Mean)	0.25 - 38.75 (2.99)

Table 7 Marginal Effects of Adaptations Measures and Risk Preference Regression

	(1) Marginal Effect	(2) Marginal Effect	(3) Marginal Effect	(4) Marginal Effect	(5) Marginal Effect	(6) Marginal Effect	(7) Marginal Effect	(8) Marginal Effect
VARIABLES	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as a test	Other changes in crop choice/management	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as a test	Other changes in crop choice/management
Risk preference (1 = Risk Averse; 0 = Risk Tolerant)	-0.0887**	-0.0488	-0.155***	-0.107***	-0.0944**	-0.0301	-0.136***	-0.106***
	(0.0448)	(0.0449)	(0.0457)	(0.0406)	(0.0446)	(0.0452)	(0.0446)	(0.0403)
Sex (1 = Male; 0 = Female)					-0.0927	0.0384	0.136	0.121
					(0.0781)	(0.0864)	(0.0902)	(0.0921)
Farm work experience (Years)					0.00747***	0.00409***	0.00299**	0.00343***
					(0.00149)	(0.00159)	(0.00142)	(0.00119)
Full time farmer (1 = True; 0 = False)					0.122***	0.0995**	-0.0107	-0.0382
					(0.0430)	(0.0449)	(0.0402)	(0.0334)
Organic only farmer (1 = True; 0 = False)					0.0383	0.00639	0.380***	-0.00846
					(0.0743)	(0.0753)	(0.0768)	(0.0541)
Organic and non-organic farmer (1 = True; 0 = False)					0.226	0.198	0.142	0.0838
					(0.183)	(0.189)	(0.181)	(0.151)

Table 7 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect
VARIABLES	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as a test	Other changes in crop choice/management	Ceasing the cultivation of one or more crops permanently	Introducing one or more crops permanently	Introducing one or more crops as a test	Other changes in crop choice/management
Farmer has agriculture related education (1 = True; 0 = False)					0.0185	-0.0368	0.0153	-0.0209
					(0.0515)	(0.0521)	(0.0472)	(0.0381)
Farmer owns land (1 = True; 0 = False)					0.128	0.200	-0.0242	0.0447
					(0.133)	(0.142)	(0.106)	(0.0998)
Size of land in rotation (Hectares)					6.59e-05	0.000299**	0.000391***	0.000265***
					(0.000134)	(0.000139)	(0.000120)	(9.22e-05)
Number of farm labors (People)					0.00125	-0.00292	-0.00237	0.00468
					(0.00879)	(0.00898)	(0.00866)	(0.00667)
Farm income (Million Danish Kroner)					-0.00295	-0.000720	-0.00588	-0.00488
					(0.00417)	(0.00419)	(0.00395)	(0.00372)
[1]Observations	676	676	676	676	676	676	676	676

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Declarations

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