DOES THE RISK ATTITUDE INFLUENCE THE FARMERS' WILLINGNESS TO PARTICIPATE IN AGRI-ENVIRONMENTAL MEASURES? – A NORMATIVE APPROACH TO EVALUATE ECOSYSTEM SERVICES

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Abstract

Agri-environmental measures are often not as accepted among farmers as expected. The present study investigates whether changes in income risks and the individual risk attitudes of farmers may constitute an explanatory approach for the low acceptance of the measures. For this purpose, a normative model is developed that calculates the premia claimed by the farmers for adopting environmental measures under the consideration of income risks and different risk attitudes. We apply this model to environmental measures aiming at an increase of the faunistic diversity of species and show that changes in income risks and the decision makers' risk attitudes can significantly influence farmers' minimum compensation claims for the participation in agri-environmental measures.

Keywords

agri-environmental measures, income risks, minimum compensation claim, premium for ecosystem services, risk attitudes

1 Introduction

With their selected land use system, farmers significantly influence the provision of ecosystem services like biodiversity (POWER, 2010). Thus, scientists and politicians agree that these services need to be taken into account when making decisions on land use. However, without corresponding incentives, ecosystem services are mostly not considered by landowners (NELSON et al., 2009). The reason for this is that economic-ecological 'win-win-situations' are extremely rare (FARBER et al., 2002); that is, from an individual farm's point of view, improvements of ecological conditions often induce additional short-term costs.

For awarding the provision of ecosystem services, a typical instrument of the European Common Agricultural Policy is agri-environmental schemes. These schemes ensure that farmers receive compensation payments for the provision of different agri-environmental measures, which are calculated according to the lost profits of an average farm plus an incentive component (PLANKL, 1998). In spite of that, AHRENS et al. (2000) point out that especially farms that have a high need for adaptation make only little use of incentive measures. A reason for this low acceptance is often too low compensation payments arising, for example, from costs for necessary restructuring of farms that are not taken into account. Moreover, there are also psychological reasons for the low acceptance of incentive measures (AHRENS et al., 2000), such as tradition or the desire to be independent.

In political practice, it is rarely considered that the implementation of agri-environmental schemes in many cases influences the extent of income risks. However, income risks can change e. g. due to the conversion of agricultural production systems, which can be concluded from the work of CHAVAS et al. (2009) and GARDEBROEK et al. (2010). Therefore agri-environmental measures, which involve the conversion of agricultural production systems, can influence income risks. For a detailed summary of the possible impact of agricultural policies on income risks, please refer to EL BENNI et al. (2012). If the implementation of agri-environmental measures involves a change in the income risks, the minimum compensation claims for the participation in agri-environmental measures of farmers that are often classified as risk averse (SERRA et al., 2008) may significantly change. In this context, the term 'minimum compensation claims' can be referred to but not set equal with the concept of the willingness to accept – in our case – compensation payments.

The stabilization of income is one of the objectives of the agricultural policy of the developed countries (TYNER et al., 2005). Besides, GREINER et al. (2009) points out that a better understanding of farmers' risk attitudes is necessary to make agricultural policies more effective and efficient. Nevertheless, only a few models exist for the investigation of the actual impact of agricultural policies on the individual farms that also consider risks and risk attitudes. One of these models is the econometric model by SERRA et al. (2008), which provides empirical proof for the influence of the risk aversion on the required incentives for going organic. This model is applied to a comprehensive panel data set of conventionally and organically operated farms in Spain. We developed the first normative, application-oriented model for determining minimum compensation claims of agricultural decision makers under the consideration of risks and risk attitudes for the participation in agri-environmental measures. The model is designed to enable scientists and politicians to determine the minimum compensation claim of farmers for any environmental measure or risk attitude using only small amounts of data.

In this study, we apply our model to environmental measures aiming at an increase of the faunistic diversity of species (FD). For this purpose, we take the example of an average grassland farm in the German federal state of Lower Saxony and examine how income risks change when reorganizing the farm. Subsequently, we quantify how the consideration of farmers' risk attitudes influences their minimum compensation claims. To do so, we use the trade-off analysis developed by ANTLE et al. (2003). However, we neither separately analyze trade-offs between incomes and ecological indicators (cf., e.g., BARTON et al., 2009; STEFFAN-DEWENTER et al., 2007; STOORVOGEL et al., 2004) nor do we analyze trade-offs between incomes and risks (cf., e.g., BRINK and MCCARL, 1978; CHAVAS et al., 2001). Referring to Lu et al. (2002), we rather investigate trade-offs between incomes, an ecological indicator (the faunistic diversity) and income risks considering farmers' individual risk attitudes. LU et al. (2002) use risk aversion coefficients from BOGGESS and RITCHIE (1988) to quantify certainty equivalents. On the contrary, the present study mainly uses risk attitude data of farmers from the German federal state of Lower Saxony collected by means of an incentive-compatible lottery according to HOLT and LAURY (2002) conducted recently by MAART-NOELCK and MUSSHOFF (2013). To our knowledge, this is the first time that this kind of model is used to investigate the minimum compensation claims for the participation in environmental measures that aim to increase the faunistic diversity.

The grassland farm examined and the methodology used are described in section 2, while results are presented and discussed in section 3. The article ends with conclusions and future research perspectives (section 4).

2 Material and Methods

2.1 The farm and its decision situation

The present study examines an exemplary farm in the German federal state of Lower Saxony that has a current total wealth of €0 and a hundred hectares of grassland currently used in equal parts for hay production and as moderate extensive permanent pasture. Using financial incentives for which a minimum amount has to be determined, the farm should be convinced to use ten hectares of land to promote faunistic diversity or, more specifically, diversity of phytophagous insects. The faunistic diversity can be increased by the following three extensification scenarios:

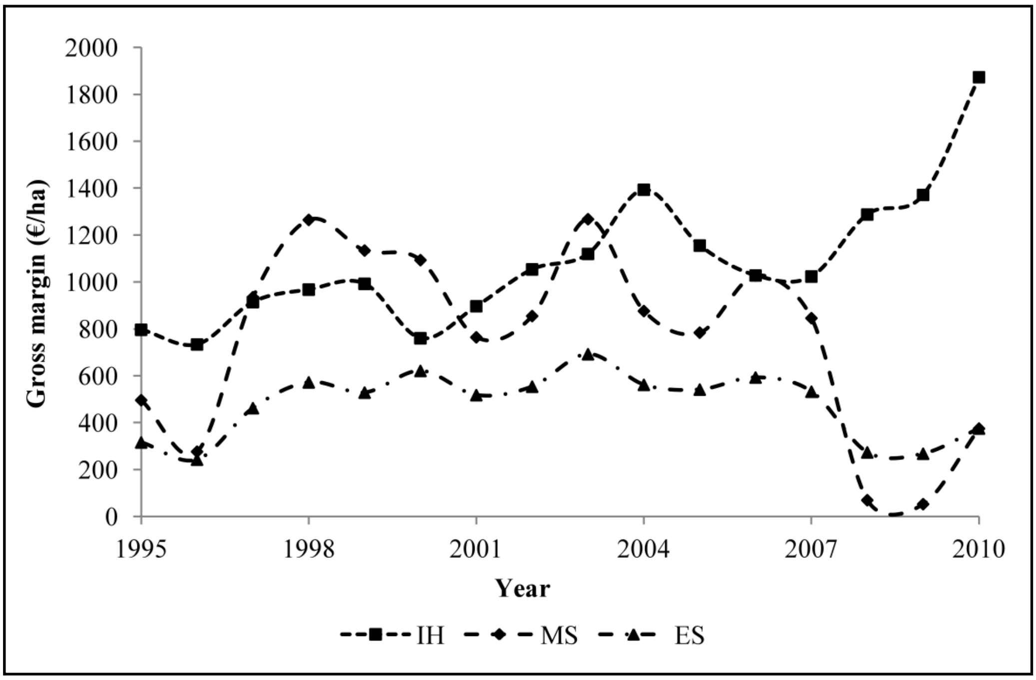
A. Switching from a fenced pasture used for intensive hay production (IH) to moderate extensive suckler cow husbandry (MS).
B. Switching from a fenced pasture used for IH to extensive suckler cow husbandry (ES).
C. Switching from MS to ES.

The land use system IH describes an intensively used hay field (four steps per year, water content of the hay: 15%, liquid manure fertilization, use of crop protection products). In the land use system MS, dry standing suckler cows (Fleckvieh cattle, 3 LU /ha) graze semi-annually on the grassland. Their replacement rate is five years. Here, the farmer aims to produce nine month old weaning calves (calving in fall), which are exclusively barn-reared, to be sold later. The land use system ES is only different from MS in the livestock density which, in this case, amounts to 1 LU/ha.

Time series of the three different land use systems for average costs and average yields of farmers in Lower Saxony (LOWER SAXONY CHAMBER OF AGRICULTURE, various years) as well as for hay (HANNOVERSCHE LAND- UND FORSTWIRTSCHAFTLICHE ZEITUNG, various years; LAND UND FORST, various years) and livestock prices (LOWER SAXONY CHAMBER OF AGRICULTURE, various years; MIESBACHER MITTEILUNGEN, various years) are available for the period between 1995 and 2010. Capacities for work, machinery and stable space are sufficient to switch to each scenario immediately. And machine capacity utilization always remains below the depreciation threshold. Thus, conversion related investments are not required in the three scenarios.

Fig. 1 depicts the gross margins development[1] from 1995 to 2010 for the three different land use systems based on the time series for costs, prices and yields.

Fig. 1: Development of the gross margins for the three land use systems IH (intensive hay production), MS (moderate extensive suckler cow husbandry) and ES (extensive suckler cow husbandry).



When looking at Fig. 1, it becomes apparent that the gross margins of the land use system MS are very volatile and those of ES are very stable. The 25% and 75% percentiles of the gross

[1] The gross margins do not include any labor costs, depreciations and interest rates of the fixed capital. Moreover, for the scenario comparison, all premia relevant to the decision are considered. Most of these premia are associated with long term contracts of more than one year.

margins are around €897/ha and €1155/ha for IH, €375/ha and €1028/ha for MS as well as €316/ha and €562/ha for ES.

Table 1 displays selected parameters of the three land use systems. On the basis of the results from KRUESS and TSCHARNTKE (2002), SCHMID et al. (2001) as well as WALLIS DE VRIES et al. (2007), the following can be assumed for faunistic diversity: An increase in faunistic diversity can be attributed to the switch from intensive hay production to (moderate) extensive suckler cow husbandry (IH to MS and IH to ES), as well as to declining grazing intensities (MS to ES).

Table 1: Parameters of the grassland use systems

	IH [a)]	**MS**	**ES**
Faunistic diversity	Low	Medium	High
Average gross margin (€/ha)	1085	758	478
Standard deviation of the gross margin (€/ha)	289	394	139
Relative 75%-VaR (€/ha)	189	382	162

a) Cost calculation is based on grass silage production data. Physical yields are calculated using the feed value tables from DEUTSCHE LANDWIRTSCHAFTS-GESELLSCHAFT (1992).

The most important risks underlying the gross margins time series for intensive hay production (IH) and suckler cow husbandry (MS and ES) are input price risks, output price risks, yield risks as well as premia risks.

A detailed comparison of these risks reveals the following differences for the land use systems:

(1) Suckler cow husbandry involves many input price risks, as the costs for herd size expansion, the fodder and basic fodder price, as well as the seed price for possible reseeding are volatile. Intensive hay production involves only one volatile input price, namely the seed price.

(2) When considering intensive hay production, the farmer is affected only by premia risks resulting from the payment of time-dependent governmental premia for agricultural land. If a farmer has suckler cows, the relevant premia risks are composed of time-dependent land, lifestock and extensification premia[2].

The gross margin fluctuations of the MS system displayed in Fig. 1 and Table 1 are higher than those of the IH system because moderate suckler cow husbandry involves more input risks (1) as well as more premia risks (2). The fact that extensive suckler cow husbandry (ES) involves the lowest gross margin fluctuations (cf. Fig.1 and Table 1) can be explained by its lowered lifestock density, which is reduced to one-third of the lifestock density for moderate suckler cow husbandry. Due to the smaller number of lifestock, the annual costs, yields and lifestock premia are two-thirds lower for extensive than for moderate suckler cow husbandry. This has risk-reducing effects and leads to stable annual gross margins for ES. For the ES system, we assume that this risk reduction has a stronger influence on the gross margin time series than the risk-increasing effect of suckler cow husbandry described in (1) and (2).

2.2 Methodology

This study aims to determine the farmers' minimum compensation claims for the extensification scenarios A to C. Usually this is done by calculating the differences in the gross margins of the individual land use systems. However, in doing so, the changes in income risks and decision makers' subjective risk attitudes would not be taken into account.

[2] Extensification premia only exist for the land use system ES.

Therefore, the present study focuses on the differences in the certainty equivalents CE. The certainty equivalent is the safe amount of money, which generates the same utility for a risk-averse decision maker as the expected value of an uncertain alternative. When putting the differences in CE in relation to the changes in the faunistic diversity FD, the trade-off between operational profits, risks and the FD is obtained in consideration of the risk attitude. The risk attitude is represented by the relative risk aversion coefficient θ. Based on this, the trade-off $TO(\theta)_S$ for the extensification scenario $S \in \{A, B, C\}$ (cf. section 2.1) is calculated using the following equation:

$$TO(\theta)_S = (CE_l(\theta) - CE_m(\theta))/(FD_l(\theta) - FD_m(\theta)), \qquad \text{for } l, m \in \{IH, MS, ES\} \text{ and } l \neq m \qquad (1)$$

The numerator of equation (1) is the minimum compensation claim $MCC(\theta)_S$ for the change of the faunistic diversity $FD_l(\theta) - FD_m(\theta)$. Using the $MCC(\theta)_S$, it is moreover possible to derive the farmers' individual risk premium RP_S. RP_S is the amount of money subjectively claimed by a risk-averse decision maker in order to take over the risk of an uncertain alternative. A risk-neutral decision maker regards risks with indifference ($RP_S = 0$), whereas a risk-seeking decision maker is willing to pay for additional risks (RP_S is negative). The risk premium the risk-averse decision maker claims in S, is calculated as follows:

$$RP_S = MCC(\theta_{risk\ avers})_S - MCC(\theta_{risk\ neutral})_S \qquad (2)$$

As the faunistic diversity of species is known for all production systems (cf. Table 1), we now only explain in detail the calculation of certainty equivalents. Our starting point is the risk utility function used by HOLT and LAURY (2002):

$$U = U(Z, \theta) = Z^{1-\theta}, \text{ for } Z > 0 \qquad (3)$$

$U(Z, \theta)$ represents the risk utility of the target variable Z. Depending on the risk attitude of the decision maker, the risk utility function is either concave (risk aversion), linear (risk neutrality) or convex (risk-seeking behavior). To measure the local risk aversion $R(Z)$, we use the equation $R(Z) = -(d^2U/dZ^2)/(dU/dZ)$, which was interpreted by PRATT (1964) in various ways. When applying this equation to the risk utility function (cf. equation (3)), the absolute risk aversion coefficient $R(Z)_{abs}$, a risk aversion measure, results:

$$R(Z)_{abs} = (-d^2U)/dZ)/(dU/dZ) = \theta/Z \qquad (4)$$

The relative risk aversion coefficient $R(Z)_{rel}$ is:

$$R(Z)_{rel} = R(Z)_{abs} \cdot Z = \theta \qquad (5)$$

If Z is income or marginal gains or losses, θ can be called partial relative risk aversion coefficient (HARDAKER et al., 2004, p. 104).

Thus, the observed risk utility function (cf. equation (3)) uses the relative risk aversion coefficient θ for the calculation of the risk utility $U(Z, \theta)$. Moreover, this function is based on decreasing absolute risk aversion (DARA) and constant relative risk aversion (CRRA). The risk utility function for the land use system l is formulated as follows:

$$U(Z_l, \theta) = Z_l^{1-\theta}, \text{ for } Z_l \in \{Z_{lt}, t = 1, \ldots, T\} \qquad (6)$$

In this study, the calculation of $CE_l(\theta)$ by means of the risk utility function (cf. equation (6)) is based on a historical simulation. Using a quasi-ex-ante thought experiment, one can ask which certainty equivalent would have resulted from different land use systems at different points in time t before. The gross margins of the land use systems IH, MS and ES from 1995 to 2010 (cf. Fig.1), which are fraught with risk, constitute the starting point. Applying them as

Z_{it}, the target variable[3], distributions of risk utilities can be determined. In this case, the risk utility for every Z_{it} is:

$$U(Z_{it}, \theta) = Z_{it}^{1-\theta} \quad (7)$$

By means of $U(Z_{it}, \theta)$ the expected utility $E[U(Z_i, \theta)\ ]$, thus the expected value of the risk utility, can be calculated as follows:

$$E[U(Z_i, \theta)\ ] = 1/T \cdot \sum_{t=1}^{T} U(Z_{it}, \theta) \quad (8)$$

On the basis of the expected utility calculated in equation (8), the certainty equivalent $CE_i(\theta)$, can be derived by using the inverse function of the risk utility function in order to determine the argument of the expected utility:

$$CE_i(\theta) = E[U(Z_i, \theta)\ ]^{1/(1-\theta)} \quad (9)$$

By varying the risk aversion coefficient, certainty equivalents $CE_i(\theta)$ for different risk attitudes can be determined.

2.3 Implementation of the Holt and Laury Lottery (HLL)

Decision makers' risk attitudes can be determined by using Holt and Laury lotteries (HOLT and LAURY, 2002; HLL)[4]. A HLL consists of two lotteries, a risky and safer one. In a total of ten decision situations in which the probability of success of the lotteries changes systematically, the participants have to choose one of the two lotteries. With the alteration of the probability of success, the potential earnings of both lotteries remain constant, but their expected values increase. In the first four decision situations, the expected values of the safer lottery are higher, while afterwards the expected values of the more risky are higher. By observing when decision makers switch to the more risky lottery, conclusions about their individual risk attitude are drawn. The HLL-value (number of safe choices) thereby characterizes the risk attitude. A HLL-value of four corresponding to a critical risk aversion coefficient θ of -0.15 describes risk neutrality. HLL-values greater (or less) than four indicate an increasing risk aversion (or willingness to take risks).

In order to quantify the general impact of different risk attitudes on the minimum compensations claims, we apply the critical risk aversion coefficients θ calculated by HOLT and LAURY (2002) for the HLL-values to our model. Furthermore, we determine the impact of the distribution of risk attitudes of real agricultural decision makers on the MCC. To do so, we combine our aggregated gross margin dataset (cf. section 2.1) with the risk attitude dataset conducted by MAART-NOELCK and MUSSHOFF (2013) with a HLL and calculate the average compensation claim of the participants using their individual critical risk aversion coefficients θ. Thereby, we assume that the distribution of the risk attitudes (HLL-values) determined by MAART-NOELCK and MUSSHOFF (2013) and therefore even their means are representative for German farmers.

In the HLL conducted by MAART-NOELCK and MUSSHOFF (2013) in 2010, 106 farmers mainly located in the German federal state of Lower Saxony are surveyed. A total of 59 of these farmers are risk averse; 17 are risk neutral and 30 are risk seeking. In concrete terms, the following pairs of HLL-values and frequencies (HLL-value/frequency) emerged: (0-1/11), (2/4), (3/15), (4/17), (5/15), (6/21), (7/10), (8-10/13). The average HLL-value is 4.9, which means that on average the farmers surveyed are slightly risk averse. MAART-NOELCK and

[3] The usual function argument of a risk utility function is wealth. In our study, we can use gross margins as function arguments because the farmers' wealth is assumed to be €0 (cf. section 2.1). For a detailed discussion on wealth-based and income-based models, see DI FALCO and CHAVAS (2006).

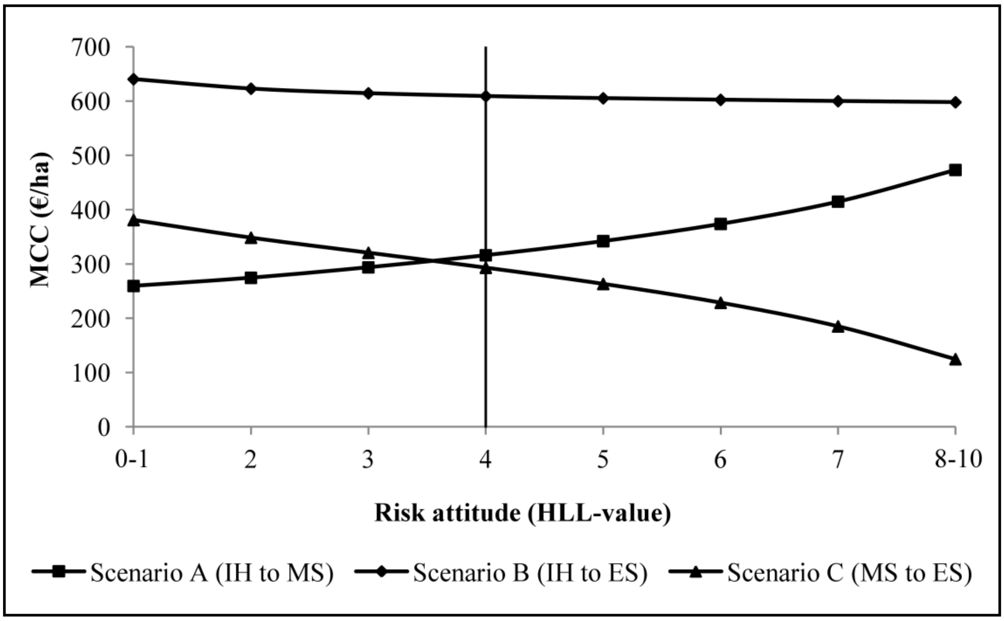
[4] For the application of the HLL method to agricultural economics, see BRICK et al. (2012) and MAART-NOELCK and MUSSHOFF (2013).

MUSSHOFF (2013) used an incentive-compatible HLL, i.e. one participant was randomly selected and received a payoff that was dependent on his/her expressed preference. The potential earnings of the two lotteries are about €10 or €385 (Lottery 1) and €160 or €200 (Lottery 2). The chance to be the winner in the HLL amounts to approximately 1%.

3 Results and Discussion

The minimum compensation claims calculated for different risk attitudes are displayed in Fig. 1 for all three extensification scenarios. Risk-neutral decision makers (HLL-value = 4), for example, claim a compensation of €316/ha in scenario A, €609/ha in scenario B and €293/ha in scenario C. Also, the risk premia RP_S (cf. section 2.2) are derived from Fig. 2.

Fig. 2: Relationship between risk attitude and minimum compensation claim for the various extensification scenarios.



When looking at the example of risk-averse farmers with a HLL-value of six, the following can be said: For switching from IH to MS (scenario A), risk-averse farmers claim a compensation of €374/ha. Therefore, they demand a risk premium of (374 - 316 =) €58/ha. Thus, when ignoring changes in income risks and decision makers' risk aversion misinterpretations would arise in policy impact assessment. If a farmer is supposed to switch from IH to ES (scenario B), there must be an incentive of at least €602/ha. Then, the farmers' risk premium is €-7/ha. If farmers are supposed to switch from MS to ES (scenario C), their minimum compensation claim is €229/ha and their risk premium is €-64/ha. The reasons for the different risk premia can be explained by looking at Table 1: In scenario A, the income risks increase when implementing the extensification. Thus, risk-averse farmers claim a risk premium, and their minimum compensation claim is higher than those of risk-neutral or even risk-seeking decision makers. In the scenarios B and C, income risks decline to varying degrees when implementing environmental measures. Risk-averse farmers prefer such situations and, compared to risk-neutral decision makers, they are willing to reduce their minimum compensation claim. Hence, the risk premium here is negative.

In order to investigate if significant differences between the minimum compensation claims exist due to income risks occurring within the three extensification scenarios, we applied the bootstrap method (number of replications: 600) and calculated the mean minimum compensation claims on the basis of the replications of each scenario. We then tested in each scenario if the mean compensation claim of a risk-neutral decision maker (HLL-value = 4) differs significantly from that of other decision makers (HLL-values = {1, 2, 3, 5, 6, 7, 8, 9, 10}). We therefore used the Wilcoxon rank-sum test because the bootstrapped minimum compensation claims were not normally distributed and independent of each other. The tests revealed that the mean compensation claims of a risk-neutral decision maker differ very significantly (α = 5 %) from that of other decision makers in all scenarios. This finding is even applicable for the participants of the Holt and Laury lottery carried out by MAART-NOELCK and MUSSHOFF (2013) with a mean HLL-value of 4.9.

Table 2 shows the expected values and standard deviations of the minimum compensation claim and risk premium of the 106 participants of the HLL conducted by MAART-NOELCK and MUSSHOFF (2013) (cf. section 2.3). Scenario B involves the highest average minimum compensation claim as well as a risk premium close to zero. In the scenarios A and C, changes in income risks and the risk attitudes, however, have a considerable effect on the incentives required because farmers, on average, claim risk premia (scenario A) or are willing to reduce their claims for diminishing their risks (scenario C).

Table 2: Average minimum compensation claim and risk premium for German farmers (N = 106) in the three extensification scenarios

Scenario	**Minimum compensation claim (€/ha)**		**Risk premium (€/ha)**	
	Expected value	Standard deviation	Expected value	Standard deviation
A	349	64	33	64
B	610	12	≈0	12
C	260	74	-33	74

4 Conclusion and Future Research Perspectives

In the present study, we developed a normative model, which enables the calculation of the minimum compensation claims for any environmental measures by considering changes in income risks and decision makers' subjective risk attitudes. Using the example of a grassland farm in the German federal state of Lower Saxony, the study reveals that income risks and subjective risk attitudes can have a considerable impact on the acceptance of environmental measures. The conducted bootstrapping indicates that income risks and risk attitudes are of great importance for tailoring the incentives of agri-environmental measures as these two features have a significant influence on the minimum compensation claims of agricultural decision makers. In addition, this study shows that risk aversion does not necessarily diminish farmers' willingness to participate in environmental measures. If income risks decrease when restructuring the farm, risk aversion leads to an increasing acceptance of the environmental measures among the decision makers. As farmers are in general classified as risk averse, from a political point of view, it is recommendable to identify and promote switching scenarios, which ceteris paribus involve a reduction in individual farm risks and aim at the political objectives. Moreover the risk reducing effect of such scenarios should be communicated to the farmers.

With a view to concrete practical conclusions, it must be considered that the approximation of farm-level data with aggregated data can lead to an aggregation bias (cf. FINGER, 2012) assessing the farm-level risks. As our manuscript focuses on the construction of a normative model, we did not take into account the aggregation bias applying the model to the three extensification scenarios. It should be noted that first if an aggregation bias exists, it is relevant for all time series. Hence, the study data of all three land use systems are comparable. Second, ignoring an aggregation bias would probably lead to an underestimation of the variability of the gross margins. In the worst case, we would therefore underestimate the influence of income risks and farmers' subjective risk attitude on the minimum compensation claims. Our present conclusions about the impact of risks and risk attitudes therefore apply to all cases and would become even more apparent when taking into account the aggregation bias. For a future application of the model, we recommend to take into account the aggregation bias by using either farm-level data or aggregated data, which are adjusted to the aggregation bias by means of a conversion factor (cf., e.g., GOODWIN, 2009).

In addition, it is to consider that first the historical simulation used in this study is based on a comparatively short time series. For future research, it is therefore necessary to work with longer time series. Second, our assumption about the representativeness of the risk attitude data conducted by MAART-NOELCK and MUSSHOFF (2013) (cf. section 2.3) can not be proven. Hence, there is a risk that this assumption does not apply and that the external validity of this study decreases due to the use of the data collected by MAART-NOELCK and MUSSHOFF (2013). However, in our opinion the assumption is appropriate because there are other authors who experimentally determined participants' risk attitude with similar results as MAART-NOELCK and MUSSHOFF (2013). For example, HOLT and LAURY (2002) carried out an experiment with students and found that a large proportion of the participants is risk averse. BINSWANGER (1980) conducted an experiment with 240 agricultural households and reached the conclusion that the participants are moderately risk averse. We therefore assume that the risk of a reduced external validity of our results is very low.

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