Latent farmer groups in yield insurance markets

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Abstract

The aim of this study is to assess how farmers differ in their willingness to pay (WTP) for crop insurance. The dimensions concerned are spatial and attitudinal. Dimensions related to farm operations, such as farm size and farmer age, are excluded from this paper, since they have already been a focus of extensive literature (Santeramo et al. 2016).

Earlier studies have revealed spatial variation in the probabilities of unfavourable weather conditions for farming (Peltonen-Sainio 2016). We hypothesised that this variation also leads to spatial variation in farmers' willingness to pay for yield insurance products. This hypothesis was formally tested with data from a choice experiment, using a latent class approach to reveal the number of latent farmer groups and differences in farmers' WTP for crop insurance.

The analysis identified three to four homogeneous farmer groups that differ significantly from each other regarding preferences for insurance attributes. Furthermore, our analysis revealed that these groups are not the same in all regions in Finland. The results provide valuable information for launching yield insurance products and related policy measures.

Keywords: crop insurance; choice experiment; attributes; latent groups

JEL classification: Q11, Q12, Q14.

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1. Introduction

Changes in local weather conditions are likely to impact on farmers' willingness to pay for insurance against unfavourable weather conditions. Earlier studies have shown that there is spatial variation in the probabilities of unfavourable weather conditions for farming in Finland (Peltonen-Sainio et al. 2016). Thus, we believe that the uptake of weather-related yield insurance products is strongly related to spatial dimensions. This hypothesis is formally tested in this paper.

In the EU member states, the main practices in preparing for crop damage include various types of joint funds for farmers and state compensation for crop damage paid on an *ad hoc* basis. These types of *ad hoc* compensation payment for crop damage amount to an average of about €920 million per year. In most cases, the state contribution to the funds and disaster assistance has been organized through various member state-specific programmes. The total funding is comprised of state and farmer contributions, and a premium subsidy. The support is often targeted at reinsurance, which is either directly managed by the state or through private insurance companies by means of state support (Bielza Diaz-Caneja *et al.*, 2009).

In developing crop insurance markets, one of the main problems to be solved is the setting of appropriate premium and subsidy levels for crop insurance schemes in order to fulfil the policymakers' objectives of a high participation rate among farmers. This is a challenging task, since farms are heterogeneous regarding their risk preferences and positions. It is typical that high-risk farmers start to over-present and low-risk farmers to under-present in the risk pool, which leads to losses on the side of the insurers (Goodwin *et al.*, 1994).

Farmers are also heterogeneous in terms of their risk attitudes (Kondouri, 2009). Previously, farmers have been divided into three groups based on their absolute risk aversion: *risk lovers, risk neutral* and *risk averse*. In this study, we were not tied to the previously used groupings or number of groups. Instead, we allowed the choice experiment data, i.e. farmers' choices, to reveal underlying and latent groups. It is important from an agricultural policy perspective to recognize these groups, since one of the key mechanisms through which agricultural support policies, even decoupled ones, may influence production decisions is their effect on farmers' risk aversion (Hennessy, 1998; USDA, 2004; Sckokai and Anto´n, 2005; Kondouri *et al.*, 2009).

Despite the lacking culture and insufficient data, markets for crop insurance are developing in the EU. One of incentives is that the EU is paying increasing attention to agricultural risk management (Meuwissen *et al.,* 2013). For example, premium subsidies could be as large as 65% of the premiums faced by farmers (EU, 2013). We conducted a choice experiment (CE) on crop insurance in Finland, and this article aims to contribute to the crop insurance literature by considering the weights that farmers assign to insurance attributes.

As the EU is paying greater attention to crop insurance and many EU countries are considering the use of crop insurance premium subsidies, it is important to develop techniques to evaluate the demand for crop insurance in order to ensure viable public policies. In this study, we applied a choice experiment, a stated-preference technique, to crop insurance markets. Thus, we dealt with a hypothetical product for which the farmers had no pre-existing knowledge.

2. Estimation method, spatial weather risks and choice experiment data

The most typical way to model CE data econometrically is with a conditional logit model. When such a model is used, it is assumed that the respondents have a similar preference structure. This implies that we assume that all farmers have the same preferences across all crop insurance attributes. If we had a strong *a priori* assumption concerning farmers' preferences for crop insurance attributes, we could have applied different models to the subregions and populations. However, as crop insurances are completely new products for Finnish farmers, we could not make such assumptions. Thus, a latent class model was used to investigate the different farmer groups. The utility U of farmer n from insurance i obtains the form:

$$U_{ni|s} = \beta_s X_{ni} + \varepsilon_{ni|s}, \quad (1)$$

where β is the vector of parameters, X is the vector of attributes, and ε is the random component in the utility function. The heterogeneity is included in the model with a class s. The farmer groups were determined purely based on the choices made by the individuals in the choice experiment. The latent class model is:

$$P_n(i|B) = \sum_{s=1}^{S} \left(\frac{\exp(\beta_s X_{ni})}{\sum_{j=1}^{J} \exp(\beta_s X_{nj})} \right), \quad (2)$$

where P_n is the probability that a farmer will select insurance i from the set of alternatives J. The parameters β_s for the attributes are estimated in an iterative manner using maximum likelihood estimation, where the number of segments S is given and the estimation is repeated several times with different numbers of segments. The best model having the optimal number of farmer groups s is selected by using model fit criteria such as the Bayesian information criterion (BIC) or Akaike information criterion (AIC). These are log-likelihood scores with correction factors for the number of observations and the number of parameters.

Discrete choice models measure the utility of respondents. Thus, the estimated model coefficients are not interpretable in economic terms. Therefore, in order to reveal the overall WTP for a crop insurance product, implicit price (IP) estimates of crop insurance attributes are calculated as:

$$IP_k = -\left(\frac{\beta_k}{\beta_p}\right), \quad (3)$$

where β_k is the parameter of *k*th attribute, and β_p is the price coefficient. WTP estimates are calculated by multiplying attribute levels with implicit prices and summing these intermediate scores up to the insurance product level.

Current methods such as random parameters logit (RPL) models could be used to calculate individual-specific estimates of implicit prices for insurance attributes (Liesivaara and Myyrä 2014). This approach would have easily solved our hypothesis that the uptake of weather-related yield insurances is strongly related to spatial weather-related dimensions. We should just calculate individual-specific estimates of implicit prices and mark these on a map point these to the map. However, RPL methods have been shown to be complicated and sensitive to predictions made by the researcher (Czajkowski et al. 2015). For this reason, we wanted to be careful and make as few assumptions by ourselves as possible. Thus, we first evaluated from the literature the most risky zones for yields, according to agronomists and meteorologists, and thereafter examined farmers' choices regarding hypothetical yield insurance purchases in these zones. The method used falls into the category of *spatial heterogeneity studies*, investigating whether the place of residence has an influence on choices among alternatives (Brouwer et al. 2010).

2.1. Data on weather risks

Weather-based yield risks have been mapped in Finland in several studies (Peltonen-Sainio 2016; Pietola 2011). The value of the risk is usually defined as the expected loss multiplied by the probability of the loss. Following this intuition, Peltonen-Sainio found that for spring cereals, a drought-induced uneven establishment of plant stands was the most valuable unfavourable form of weather-related yield loss in Finland. Retarded growth induced by early summer night frost was also found very harmful in terms of the value of yield losses. Frost was additionally recognized by Pietola *et al.* (2011). They recognized that frost is the most critical weather-related factor in the middle of June. The point estimate for the yield loss caused by frost was 2,000 kg/ha with a standard error of 1,500 kg/ha. Compared to the average barley yield in Finland of 3.470 kg/ha, this means that frost might sometimes destroy the whole yield in the middle of the growing season (http://statdb.luke.fi/PXWeb/pxweb/fi/LUKE/).

We connected our choice experiment data, which are recognized and coded with ELY region codes (regions of operation of the Centres for Economic Development, Transport and the Environment; Fig. 1), with findings from weather-related yield loss studies (Fig. 1 and Table 1) to identify the most risky areas for weather-based yield losses. For the estimation procedure, the dataset was divided in subgroups and models were fitted independently for these subgroups. The limiting factor in this task is the number of observations, which limits the number of subgroups and thus the areal accuracy of the analysis.

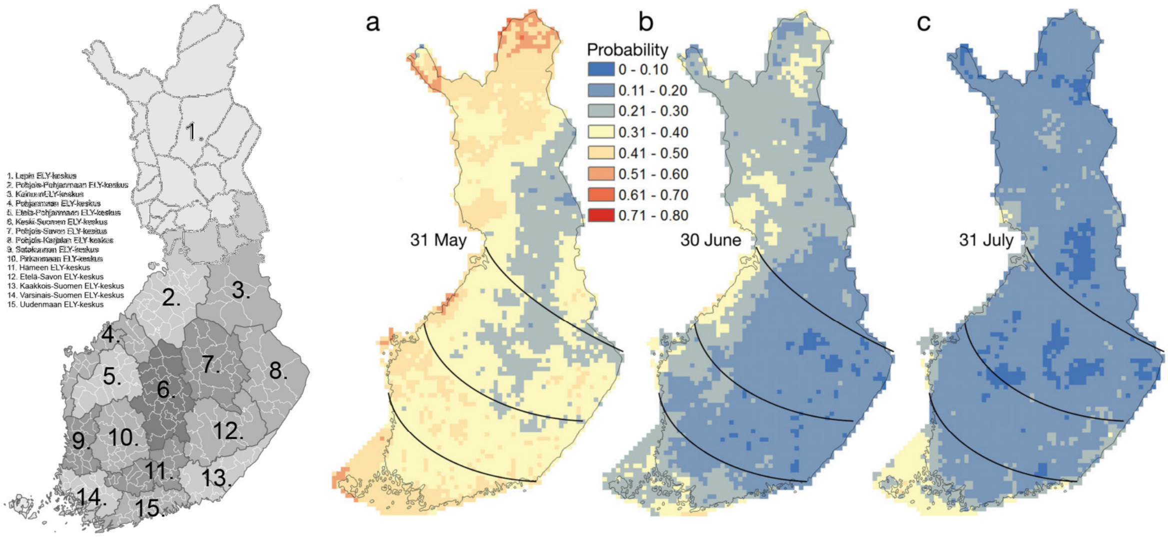

Figure 1. Regions of operation of the Centres for Economic Development, Transport and the Environment (ELY Centres) in Finland, and variation in the probability of drought lasting for at least 2 weeks up to (a) the end of May, (b) the end of June and (c) the end of July (Peltonen-Sainio *et al.* 2016).

Table 1. Probabilities of night frost in some cities in Finland (Peltonen-Sainio *et al.* 2016). Cities are connected with ELY regions by location numbers. High probabilities of frost are indicated with an *italic* font.

Location		Latitude	Longitude	Early summer		Mid-summer
ELY region number	Name			–2 to –5 °C	≤–5 °C	≤–1 °C for ≥5 h
14	Turku	60.5°N,	22.3°E	0.06	0.03	0.12
14	Mietoinen	60.6°N,	21.9°E	0.14	0.03	0.09
11	Jokioinen	60.8°N,	23.5°E	*0.21*	0.02	0.22
13	Kouvola	60.9°N,	26.9°E	0.13	0.00	0.13
6	Jyväskylä	62.4°N,	25.7°E	0.19	0.02	*0.33*
5	Seinäjoki	62.9°N,	22.5°E	*0.26*	0.07	*0.33*
8	Tohmajärvi	62.2°N,	30.3°E	*0.23*	0.05	0.13
7	Siilinjärvi	63.0°N,	27.8°E	0.06	0.00	0.09
7	Maaninka	63.1°N,	27.3°E	0.09	0.00	0.02
2	Siikajoki	64.7°N,	25.1°E	*0.23*	0.05	*0.29*
2	Oulu	64.9°N,	25.3°E	0.10	0.00	0.10

2.3. Choice experiment data

The choice experiment survey was conducted in 2012. The survey was sent to a total of 5,000 farmers in Finland. In the questionnaire, respondents were shown six crop insurance product cards. Each choice card presented two different crop insurance products with varying attributes. Farmers were asked to select the most suitable crop insurance product for them. Respondents could also select a no-purchase option, i.e. not to purchase crop insurance at all (Table 1).

Other attributes besides the price chosen for the insurance products were the insurance cover (identified as the deductible in Europe), type and expected indemnity (scale). The insurance cover and expected indemnity are essential features of crop insurance (Barnett *et al.*, 2005). Coverage determines the share of the loss (deductible) that is covered by the farmer. The expected indemnity attribute defines the level of the indemnity payment a farmer receives if the farm yield (or particular index in the case of index insurances) falls below the trigger level. In many of the insurance products developed in the US, farmers can change the scale and modify the insurance product to suit their farm. Thus, scale is treated as an individual attribute in CE designs and it describes the most likely indemnity payment of a farm, if it is eligible for compensation.

An example of a choice card presented to farmers and the attribute levels used in this study is provided in Table 1. In this study, the expected indemnity was determined for one hectare and it could have three different levels, which were €100, €300 or €600/ha. The insurance coverage could be 90%, 80% or 70%. In the choice sets, the term 'deductible' was used instead of 'cover' to better describe the share of losses farmers must cover by themselves. The insurance type could be index or farm-specific insurance (Table 2). In farm-specific insurance, inspection is needed if the farm experiences a crop loss. In index insurance, compensation is based on regional indices, e.g. the regional yield. If the value of the index falls below the deductible level, the insured farmer is eligible for compensation, even if the farm has not experienced crop damage. Because Finnish farmers have no prior experience of market-based crop insurance, the surveyed farmers were provided with information on the insurance attributes on the choice cards before they were asked to complete their insurance choices. All four attributes were described in detail.

Table 2. Choice card and attribute levels.

INSURANCE CARD 1	Insurance 1	Insurance 2	No buy		levels
Insurance premium €/hectare	12	16	**I would not purchase insurance**		€4–32/ha
Deductible	20%	20%			10%, 20%, and 30%
Insurance type	Yield index insurance, farm inspection is not needed.	Farm yield insurance, inspection of loss at the farm is needed.			Yield index farm yield
Expected compensation €/hectare	300	600			€100/ha €300/ha €600/ha
MY CHOICE	□	□	□		

3. Results

Discrete choice models measure the utility of respondents (Table 3). Thus, the estimated model coefficients are not interpretable in economic terms, despite their signs. Therefore, we calculated implicit price (IP) estimates of crop insurance attributes (Table 4).

As the first step for spatial analysis, we used ELY districts as a covariate in the latent class model. While insurance attributes were entered in the regression model for the choices, covariates were used to predict farmer group membership. We used a model with three farmer groups as the default based on our earlier analysis (Myyrä and Liesivaara 2015). The results from this model indicated that the data were not informative enough to improve predictions regarding farmer group membership with the discrete ELY region variable. Consequently, we continued the spatial analysis by grouping ELY regions into larger geographical areas to reveal whether farmer groups can be geographically distinguished.

Based on weather data, we grouped ELY regions in high weather risk zones into one subgroup and the rest of the regions into another subgroup. For the high weather risk zones, we selected ELY region 4 (Pohjanmaa) due to a high probability of drought lasting for at least 2 weeks, ELY region 2 (Pohjois-Pohjanmaa) due to drought and frost risks and ELY regions 5 (Etelä-Pohjanmaa) and 6 (Keski-Suomi) due to frost risks (Figure 1 and Table 1). The remaining ELY regions formed an area group in which weather-related yield risks are lower. We therefore named the weather risk-based area subgroups as "risky" and "other".

A model with three farmer groups was selected based on Bayesian Information Criterion (BIC) statistics and reasonable farmer group sizes for the subgroup "risky". In the estimation based on this data subgroup, the Wald p-values (Table 3) indicate that the attributes are jointly significant, while the Wald* p-values show that only the insurance type attribute is farmer group dependent. However, this is very important for economic interpretation of the results, because it reveals that implicit prices differ between farmer groups. For the data subgroup "other", we selected a model with four farmer groups based on BIC statistics. In this case, the model produces one extra farmer group that seems to have clearly different preferences for insurance attributes compared to the other farmer groups within the subgroup "other".

The price coefficient is negative in both subgroups, as expected, and significant in all farmer groups. This implies lower utility and a lower probability of choosing an insurance product as price increases. The deductible attribute is also negative, as expected. As farmers' own share of the risk increases (increasing deductible, i.e. decreasing cover), they are less willing to purchase insurance. However, a small group of farmers (8%) in the subgroup "other" associate positive utility with an increasing deductible. This is an unexpected result and we cannot derive any other explanation for this except that they had somehow misunderstood the choice card (Table 2). The scale coefficient is positive and significant. A larger expected indemnity payment increases the utility of farmers from insurance. A clear exception among insurance attributes was the insurance type, which only turned out to be significant in the data subgroup "risky". The main result from the analysis is that in areas where weather-induced risks are higher, farmers could be clearly divided into those who prefer farm-based insurance and to those who prefer index insurance. However, index insurance is largely preferred in other areas (subgroup "other").

Table 3. Latent class models for insurance choices.

Model for Choices, subgroup "risky"	Farmer group 1	Farmer group 2	Farmer group 3	Overall	
R²	0.3441	0.1781	0.2290	0.5394	
R²(0)	0.4286	0.9089	0.3415	0.6052	
size	0.38	0.36	0.26		
Attributes				Wald p-value	Wald* p-value
Reference level	0	0	0		
1	-1.9677	-1.9703	0.2523	0.14	0.14
2	-1.7742	-3.0339	0.0195		
3	3.7419	5.0041	-0.2328		
Price	-0.0895	-0.5149	-0.0730	<0.001	0.44
Deductible	-4.6205	-6.6460	-2.3728	0.03	0.74
Scale	0.0045	0.0042	0.0041	<0.001	0.97
Insurance type (farm insurance =1)	1.0084	0.3402	-0.4860	0.03	<0.01

Model for Choices, subgroup "other"	Farmer group 1	Farmer group 2	Farmer group 3	Farmer group 4	Overall	
R²	0.0032	0.4901	0.3932	0.4985	0.6241	
R²(0)	0.8222	0.5504	0.4698	0.6252	0.6625	
size	0.36	0.33	0.24	0.08		
Attributes					Wald p-value	Wald* p-value
Reference level	0	0	0			
1	-2.4022	-1.7492	-1.5337	5.6138	<0.001	<0.001
2	-2.4006	-1.6350	-1.2076	5.6004		
3	4.8028	3.3842	2.7413	-11.2141		
Price	-0.0079	-0.241	-0.0508	-0.2665	<0.001	<0.001
Deductible	-4.660	-5.6306	-5.9889	7.0988	<0.001	<0.001
Scale	0.0005	0.0080	0.0061	0.0008	<0.001	<0.001
Insurance type (farm insurance =1)	-0.0719	-0.6816	-0.2903	0.6686	0.33	0.39

The reference level for all attributes is set to 0. Constant 3 refers to the "no purchase" option.
All estimated parameters are significant at the 99% level based on z-statistics.

Implicit prices (IPs) are the marginal rates of substitution between price and product attributes. These reveal how willing farmers are to trade one attribute for another, given that the bundle of these attributes gives constant utility. In this analysis, it turns out that insurance type is the key factor distinguishing between the data subgroups formed based on weather-based risks. In areas facing larger probabilities of weather-induced yield risks (data subgroup "risky"), farmers' preferences for farm insurance products that require inspection of losses at the farm differ significantly between farmer groups. The implicit price for farm types of insurances dominated the decision making in a large group of farmers (38% + 26%, farmer groups 1 and 3) in these areas. However, the rest of the farmers in Finland are indifferent regarding the insurance type or prefer index-type insurances, indicated with a negative implicit price for the insurance type (Table 4).

Table 4. Implicit prices for insurance attributes and WTP estimates for an example insurance product. The implicit price for the insurance type should be added to calculate WTP for farm insurances.

"Risky" IP (€/ha)	Shallow farm loss protector	Catastrophe dodger	Average farmer
Deductible (+10%)	-5.2	-1.3	-3.3
Scale (+ €100/ha)	5.0	3.8	5.6
Insurance type (farm insurance =1)	*11.2*	*0.7*	*-6.6*
WTP*)	-0.6	-1.5	6.9
WTP**)	14.6	16.4	21.2

"Other" IP (€/ha)	Full-cover seekers	Catastrophe dodger	Balance sensitive	Irrational
Deductible (+10%)	-59.0	-2.3	-11.8	2.7
Scale (+ €100/ha)	6.3	3.3	12.0	0.3
Insurance type (farm insurance =1)	*-9.1*	-2.8	*-5.7*	2.5
WTP*)	-158.1	3.0	0.6	8.7
WTP**)	-86.5	11.9	36.4	6.9

*) Index insurance, deductible 30% and scale €300/ha
**) Index insurance, deductible 20% and scale €500/ha

Next, we analysed the differences between three farmer groups in the subgroup "risky". The first farmer group, representing 38% of farmers, could be named as '*shallow farm loss protectors*'. Their IP for the deductible is highly negative compared to the rest of the farmers. They are not willing to pay for high deductible levels and thus only purchase insurances targeted at shallow losses. The insurance purchases of *shallow farm loss protectors* are largely affected by the insurance type offered. Their IP for the scale is in the same range as for farmers in other groups. The second farmer group, representing 36% of farmers, have a small negative IP for the deductible and a reasonably high IP for the scale. They are willing to purchase insurances that have both a high deductible and scale. This indicates that they are willing to handle a large part of yield risk by themselves with their agronomist skills. Their interest regarding yield insurances is in the catastrophic type of insurances for events that seldom occur, but might be significant in terms of damage. Such damage could not be avoided with agronomist skills. We name this group as '*catastrophe dodgers*'. The third farmer group, representing 26% of farmers, prefer index insurances, and their willingness to pay is positive for both example insurances presented in Table 4. Thus, we name this group as '*average farmers*', since index insurances are based on regional yield averages and farm inspections are not needed. Farmers in this group consider that yield variation on their farm follows the variation in average regional yields, and that they could therefore receive sufficient insurance coverage by purchasing index insurances.

According to the model statistics, farmers in the subgroup "other" could be divided into four groups based on their choices. The largest group, representing 36% of farmers, have a very high negative WTP for any reasonable yield insurances. The large negative IP for the deductible indicates that these farmers expect yield insurance to cover all the yield damage without any farmer contribution to the cost of yield damage. We name this group as '*full-cover seekers*'. We can also recognize *catastrophe dodgers* in the "other" subgroup, which forms an almost identical group of farmers to those in the "risky" subgroup regarding their implicit prices for insurance attributes. The third largest group is very sensitive to the balance between cover and scale, and we name these farmers as '*balance sensitive*'. Implicit prices for these attributes, as measured with a deductible of 10% and scale of 100 €/ha, are close to each other but opposite in signs. Thus, they have close to zero WTP for index insurance with a deductible of 30% and a scale of €300/ha. If the scale is increased and the deductible decreased, their WTP for yield insurance increases sharply. '*Balance sensitive*' farmers prefer index insurances. The fourth group of farmers made irrational choices. They represent 8% of farmers and we name this group as 'irrational'.

Estimated implicit prices for insurance attributes provide guidance in evaluating farmers' willingness to pay (WTP) for insurance products. If WTP turns out to be higher than the insurance price, it is expected that farmers will enrol in insurance schemes.

4. Conclusions

In this study, we examined the demand for crop insurance in Finland. We conducted latent class analysis using choice experiment data to reveal latent groups of Finnish farmers, in addition to farmers' implicit prices for insurance attributes. The analysis revealed several homogeneous groups that differ significantly from each other. Our results confirm that farmers do not have uniform preferences for yield insurance attributes. A new result from this analysis is that farmers' preferences vary between regions formed based on weather risks for arable farming.

Currently, the Finnish government is developing its policy regarding yield insurances. As it will no longer introduce crop insurance premium subsidies, the government's focus has shifted to the future role of catastrophic assistance. Our results confirm that well-functioning and uniform catastrophic assistance rules for the whole of Finland would be challenging to implement. Our analysis recognized a group of farmers who are willing to enrol in insurance schemes targeted at the catastrophic type of yield damage. The relative size of this group of farmers is 33–36%. We have named this group as 'Catastrophe dodgers'. Conversely, our results indicate that a large proportion of farmers are not interested in insuring against catastrophic type events. This result is shown to very strong in the data subgroup "other", representing areas that are not zones of high weather risk for arable farming in Finland, among a farmer group we name as '*full-cover seekers'*.

An important policy issue in the EU is the implementation of risk management tools in rural development programmes. The EU is keeping insurance types (farm-based insurance and index insurance) open and eligible to premium subsidies. Based on our results, this flexibility seems well justified. However, our results indicate that setting of the rules for premium subsidies by the EU Common Agricultural Policy (CAP) will not be sufficiently flexible to take into account the differing needs of farmers for agricultural risk management in terms of insurance cover. If the EU drives for efficient risk management policies for agriculture, flexibility will be needed in the legislation, and shallow-loss (low deductible) insurances will also need to be introduced to equally handle all risk-prevention needs of farmers. Currently, shallow-loss insurances are being debated in the US, and this debate should also be extended to the EU. In our analysis, the *shallow farm loss protector* group turned out to be the largest farmer group in the data subgroup "risky", representing high weather risk zones for arable farming in Finland.

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