Doctoral School of Business and Management

THESIS SUMMARY

Anna Zubor-Nemes

Risk management in crop farming

Ph.D. thesis

Supervisor:

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professor

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Agribusiness Department

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1. RESEARCH BACKGROUND AND OBJECTIVES

Crop production has a major role in Hungary. Two thirds of the farms are mainly engaged in crop farming (KSH, 2020), and crop production represents about 60 percent of total agricultural output (Eurostat, 2020). From a risk management point of view, this sector is most affected by weather-related risks. Crop production is riskier than other sectors because the biological processes are time consuming, consequently, the results are obtained only long after the decision-making (Kovács, 2009).

The agricultural sector is heavily exposed to the impact of climate change and the more common extreme weather events. As an example, heatwaves have become much more frequent, longer and more intense in the Carpathian Region for the period 1961-2010 (Spinoni *et al.*, 2015). Similarly, much of Europe is affected by the increased frequency of heatwaves (IPCC, 2014). Changes in precipitation are also discernible in Hungary. The reduced precipitation occurs in a more intensive pattern, consequently, the frequency of extreme rainfall events increased (OMSZ, 2015).

Adapting to climate change is an increasingly important priority for decision makers around the world, which indicates the growing awareness about the need for agricultural risk management (OECD, 2011). Hungary is exposed to several natural hazards, such as drought, hail, thunderstorm, spring frost and winter frost. This exposure can have significant impacts on agricultural production. To deal with the financial impacts caused by natural hazards, crop insurance is an appropriate tool (Di Falco *et al.*, 2014). In Hungary, a two-scheme risk management system was introduced in 2012. This system offers premium subsidised crop insurance for farmers, in order to make the usage of crop insurance more attractive for them.

In addition to crop insurance purchase, to maximize agriculture's mitigation potential regarding to weather-related risks, there is a need for investments in technological innovation and agricultural intensification related to increased efficiency of input usage (Vermeulen *et al.*, 2012). On the other hand, technical efficiency improvement also contributes to decrease agriculture's impact on climate change (Bell *et al.*, 2014), for example, through the more efficient use of natural resources.

The aim of the dissertation is to explore the influencing factors of crop insurance take-up and evaluate the effect of crop insurance purchase on technical efficiency and farm investment, and analyse the interrelationship between these factors. The research is motivated by personal, practical and scientific reasons. As for personal reasons, I have been part of the team in Research Institute of Agricultural Economics (predecessor in title of the Institute of Agricultural Economics Nonprofit Kft.), which has analysed and evaluated the operation of the Hungarian National Risk Management System since 2012. This raises my personal interest in deeper understanding of crop insurance demand. The topicality of the research is given by the increasing pressure on agriculture due to climate change, which might be reduced by paying more attention to weather-related risk management, production efficiency and farm investment. The understanding of how these factors interact and which factors influence the insurance decision of the farmers raise the scientific interest.

The dissertation is based on three articles whose results complement each other. The first paper investigated the spatial pattern of crop insurance take-up at settlement (LAU 2) level in Hungary. The second paper explored the influencing factors of crop insurance purchase, and investigated the impact of crop insurance take-up on farms' technical efficiency among Hungarian arable farms based on farm level data from FADN database. The last paper extended the analysis carried out in the second article. In addition to study the influencing factors of crop insurance take-up, the interaction between crop insurance usage, technical efficiency and farm investment was also explored.

2. RESEARCH METHODOLOGY

2.1. Research questions

The aim of the research is to identify the influencing factors of crop insurance take-up and evaluate the interrelationship between crop insurance usages, technical efficiency and farm investment decision. The related research questions are the follows.

RQ1: What is the spatial pattern of crop insurance take-up?

RQ2: What are the factors that influence the farmers' crop insurance decision?

RQ3: Does crop insurance take-up affect technical efficiency?

RQ4: How to describe the interrelationship between crop insurance take-up, technical efficiency and farm investment?

2.2. Hypotheses

The answers the research questions were sought along the following hypotheses.

H1: The intensity of insurance use has a spatial pattern, as farmers' insurance decision are influenced by the decisions of nearby producers.

The issue of crop insurance demand has been a subject of numerous research studies, and it was found that the demand of crop insurance was influenced by several factors, such as risk management substitutes, farmers' risk perception and attitude, farm and farmer characteristics, production risk, employed production practices and the price of insurance premium (Baráth *et al.*, 2017; Finger and Lehmann, 2012). However, only a few studies have investigated the role of neighbouring farms (Adhikari *et al.*, 2010).

As the first hypotheses, a significant spatial pattern is expected in subsidised insurance usage at settlement level, i.e., farmers' insurance decision is expected to influenced by the decision of nearby producers.

H2: Crop insurance level is influenced by the rate of fruit production and vegetable production in total crop production.

The differences in the insurance premium rates between arable, fruit and vegetable crops influence crop insurance demand. The relative high insurance premiums for fruit crops compared to arable and vegetable crops discourages the willingness of farmers to purchase insurance (Keményné Horváth *et al.*, 2017). However, vegetable producers expected to be more likely to take out for crop insurance due to the high-risk exposure and the moderate premium rates. It is assumed that the differences in crop insurance take-up are significant regarding to production structure.

H3: Crop diversification increases crop insurance usage.

The role of diversification in crop insurance take-up have been studied by numerous researchers in terms of both on-farm diversification and off-farm diversification, although the results are inconclusive concerning the effect of diversification. On the one hand, diversification reduces income risk, thereby it can be a substitute for crop insurance, consequently it decreases crop insurance usage (Calvin, 1992; Di Falco *et al.*, 2014; Goodwin, 1993). On the other hand, some authors found positive relationship between diversification and crop insurance usage explained by farmers' risk averse attitude (Enjolras and Sentis, 2008; Mishra *et al.*, 2004). This hypothesis is based on the assumption that farmers who diversify their crop portfolio are more likely to have risk averse attitude (Enjolras and Sentis, 2008), and they are more likely to purchase crop insurance.

H4: Farm size impacts positively on crop insurance take-up.

A large body of literature found positive association between farm size and crop insurance use (Baráth *et al.*, 2017; Barnett *et al.*, 1990; Calvin, 1992; Di Falco *et al.*, 2014; Enjolras and Sentis, 2008, 2011; Goodwin, 1993; Sherrick *et al.*, 2004), which was explained in different ways. Firstly, larger farms might insure more acres which generates higher crop insurance commission that motivates agents to take out insurance with larger farms (Barnett *et al.*, 1990). Secondly, crop insurance is affordable only larger farms due to hight premium rate (Enjolras and Sentis, 2011). Thirdly, greater land induces greater incentive to hedge against extreme weather conditions (Di Falco *et al.*, 2014). It is assumed that there is also a positive relationship between farm size and crop insurance demand among Hungarian farmers.

H5: Older and higher educated farmers are more willing to adopt crop insurance to reduce production risk.

Farmers' age and education can also have an impact on crop insurance take-up. Some authors argued that older, more experienced farmers were more willing to pay insurance (Finger and Lehmann, 2012; Sherrick *et al.*, 2004), while other arrived at the opposite result, arguing that older farmers might be less risk averse (Calvin, 1992; Enjolras and Sentis, 2008). However, the literature suggests, that more educated farmers expected to be more interested in insurance coverage (Enjolras and Sentis, 2008; Finger and Lehmann, 2012). This hypothesis is based on the assumption that older farmers are more experienced and more risk averse, consequently, they are more likely to purchase crop insurance. In addition, education contributes to increased management effectiveness, including the adaptation of several risk management tools, like crop insurance.

H6: Increasing financial performance encourages crop insurance purchase.

As shown by Baráth *et al.* (2017), Hungarian farmers face budget constraints, consequently, an increase in economic performance in terms of profit margin and total factor productivity might leads to an increase in crop insurance demand. It is assumed that an increase in ROE also encourages crop insurance take-up among Hungarian farmers.

H7: Crop insurance take-up influences positively farms' technical efficiency.

The relationship between crop insurance usage and technical efficiency can be ambiguous. On the one hand, crop insurance provides a safety net, consequently, the producer receives income even in the case of natural damage. This can reduce farmers' effort, thereby decreases technical efficiency. However, unlike the subsidies, crop insurance compensation is not received if the yield reduction is due to the farmer's fault, not because of any extreme weather events. Furthermore, the amount of compensation does not cover the entire amount of damage incurred. On the other hand, the safety provided by the insurance also might contribute to introduce new technology and to develop technical efficiency. In addition, crop insurance has a premium cost which can pressure the farmer to improve technical efficiency in order to generate additional income to compensate it (Zubor-Nemes, 2021). This providing support for the hypothesis about positive relationship between crop insurance take-up and technical efficiency.

H8: Crop insurance take-up, technical efficiency and investment interact positively.

All the three factors, crop insurance take-up, technical efficiency development and investment can play a role in improving farms' resilience to the impact of extreme weather events and climate change (Bell *et al.*, 2014; Di Falco *et al.*, 2014; Vermeulen *et al.*, 2012). It is assumed that these factors interact positively, and reinforce each other's impact on farms' resilience to weather-related risks.

2.3. Methods and data

The empirical analysis, regarding to the spatial pattern of subsidised crop insurance take-up, used crop insurance data collected by Research Institute of Agricultural Economics (AKI) and utilised area data from the Integrated Administration and Control System (IACS) at settlement (LAU 2) level for the period 2012-2016. Moran's *I* index was used to evaluate the spatial pattern of subsidised crop insurance usage and the degree of spatial association between settlements (Cliff and Ord, 1981; Fischer and Wang, 2011). Dynamic spatial autoregressive model (SAR) was applied to examine the factors influencing crop insurance take-up (Belotti *et al.*, 2017), considering the type of insurance and the percentage of eligible area insured, also taking into account the spatial relationship, lagged insurance rate, cultivation structure and average insurable farm size.

The examination of the influencing factors of farmers' insurance decision and of the impact of crop insurance usage on technical efficiency among Hungarian arable farms was based on FADN data for the period 2001-2014. The factors affecting insurance demand were explored by using pooled probit model and random effects (RE) probit model (Baltagi, 2005; Wooldridge, 2010, 2013). The effect of crop insurance and other environmental factors (such as farm size, investment rate, indebtedness rate and information of farmers' characteristics) on technical efficiency was evaluated by using two-stage Data Envelopment Analysis (DEA) method. The first stage refered to the estimation of technical efficiency scores which were regressed on crop insurance take-up and other environmental variables in the second stage by applying multivariable truncated regression analysis with double bootstrap. This method was pioneered by Simar and Wilson (2007) and extended by Du *et al.* (2018).

The interrelationship between insurance demand, technical efficiency and farm investment among Hungarian arable farms was investigated on FADN data for the period 2001-2019. Firstly, the estimation of technical efficiency scores was estimated by applying DEA model with bootstrap method (Simar and Wilson, 1998, 2007). Secondly, a system of simultaneous equations was used to examine the relationship between insurance demand, technical efficiency and farm investment, considering other factors as well, such as farm size, concentration, production intensity, subsidies and information of farmers' characteristics (Amemiya, 1979; Cameron and Trivedi, 2009; Maddala, 1983; Newey, 1987).

3. RESEARCH RESULTS

3.1. Reflections on the research questions and hypotheses

The dissertation investigated four research questions and tested eight hypotheses on crop insurance take-up, which are summarized in Table 1.

The first research question aimed to explore the spatial pattern of subsidised crop insurance take-up. The related hypothesis (H1) was tested by Moran's *I* index and dynamic spatial autoregressive model. The calculations were based on crop insurance data aggregated to settlement (LAU 2) level for the period 2012-2016. The results of both methods confirmed the existence of spatial pattern, namely, nearby producers influenced positively farmers' insurance decision. The 'B' and 'C' type insurance became more clustered during the period examined. However, the 'A' type insurance became less clustered but by 2016, although the overall take-up of this type of insurance increased. The existence of spatial relationship in insurance take-up is in line with the findings of Adhikari *et al.* (2010), regarding the choice between yield or revenue insurance. Their theory may be also applicable to insured versus non-insured farmers, namely, high level of crop insurance use may induce more intensive insurance take-up in nearby settlement. In addition, neighbouring farms can face similar weather-related risks which also provide an explanation for the similar insurance decision. In the light of these results, the first hypothesis is accepted.

The second research question and the related hypotheses (H2-H6) focused on the influencing factors of crop insurance take-up. The hypothesis of production structure (H2) was tested by dynamic spatial autoregressive model for the same dataset as in the case of the previous hypothesis. The results of the model confirmed the negative role of the high rate of fruit production and the positive effect of high rate of vegetable production on subsidised insurance use for all types of subsidised insurance taken together and for 'B' type taken separately. A high share of fruit production discourages participation in the subsidised insurance system, which can be explained by the typical damage scale, the relative high insurance premium for fruit crops and the low-risk appetite of insurers. Hail and spring frost can severely damage fruit crops and can also cause a high level of financial loss at the farm level, consequently farmers are entitled to compensation from the first, damage mitigation scheme. For fruit crops, the farmer's damage mitigation scheme contribution is relatively low compared to arable crops. As a result, the first scheme is an alternative way to insure for fruit growers. However, vegetable producers are more likely to purchase for crop insurance, which can be explained by the high-risk exposure and the moderate insurance premium rates. The production structure is insignificant for all risk (‘A’ type) and ‘C’ type insurances. It can be explained by the fact that the ‘A’ type was not available for most of fruit crops and vegetable crops for the period examined and the non-insurable areas were excluded from the analysis. In addition, fruit and vegetable producers preferred the ‘B’ type insurance to ‘C’ type if it was available for the crop chosen, because in case of support reduction the premium support is higher for ‘B’ type than for ‘C’ type. Based on these results, the second hypothesis is only partly accepted.

The hypothesis of crop diversification (H3) was tested by applying pooled probit model and random effects probit model on FADN data for the period 2001-2014, and system of simultaneous equations for the period 2001-2019. Concentration of crop production as an inverse measure of crop diversification was considered when testing hypothesis H3. The negative impact of concentration was confirmed by all of the models applied. This result suggests that a farmer with a diversified crop production structure may also willing to purchase crop insurance to further reduce weather-related risks. Hungarian farmers do not tend to treat crop diversification as a substitute for crop insurance usage, rather it is a complementary tool to reduce risk. Regarding to the results, the third hypothesis is confirmed.

The effect of farm size (hypothesis H4) was investigated in all the three papers. The first paper analysed the impact of farms’ average insurable area on crop insurance take-up at settlement level by using dynamic spatial autoregressive model. Here, the influence of farm size was significant only for all types of insurances together, but insignificant for ‘A’, ‘B’ and ‘C’ type separately. The other two papers explored the role of farm size on crop insurance demand at farm level. The pooled probit model and random effects probit model revealed significant positive impact of farm size on crop insurance usage for the period 2001-2014. However, the impact of farm size was eliminated by the method of system of simultaneous equations for the period 2001-2019. In view of these results, the fourth hypothesis is only partly confirmed.

The hypothesis related to farmers’ characteristics (H5) was tested by using pooled probit model and random effects probit model for the period 2001-2014, and system of simultaneous equations for the period 2001-2019. The pooled probit model and the system of simultaneous equations revealed significant positive relationship between farmers’ age and crop insurance usage, while result of the random effects probit model suggested that age had no significant impact on crop insurance demand. Most of the models applied revealed, that older farmers might be more risk averse; therefore, they were more likely to purchase crop insurance. The positive effect of education on crop insurance demand was supported by the pooled probit model and the random effects probit model, but the system of simultaneous equations eliminated the direct impact of education on crop insurance usage. Consequently, this hypothesis is only partly accepted.

The hypothesis of financial performance (H6) was tested by applying pooled probit model and random effects probit model for the period 2001-2014. These models revealed that ROE had not significant effect on crop insurance demand, suggesting that the premium subsidies, which were available the end of the period examined, helped to relax the budget constraints on Hungarian farms. This hypothesis is not supported by the models applied.

The third research question and the related hypothesis aimed to explore the relationship between crop insurance take-up and technical efficiency. The hypothesis of technical efficiency (H7) was tested by using two-stage DEA method with double bootstrap for the period 2001-2014, and system of simultaneous equations for the period 2001-2019. The first model investigated the role of crop insurance take-up in terms of the amount of insurance premium per hectare, the second model treated insurance demand as a dummy variable. Both of the models revealed significant and positive effect of crop insurance purchase on technical efficiency, suggesting that the safety provided by the insurance also might contribute to introduce new technology and to develop technical efficiency. According to these results, this hypothesis is confirmed by both models applied.

The fourth research question is about the interrelationship between crop insurance demand, technical efficiency and farm investment. The related hypothesis (H8) was tested by system of simultaneous equations for the period 2001-2019. The results indicated both technical efficiency and farm investment encouraged crop insurance take-up, suggesting that managers of farms with higher technical efficiency and higher level of investment also consider carefully other aspects of production, like crop insurance decision. In addition, crop insurance purchase increases technical efficiency and farm investment by providing a safety net. However, there is no significant relationship between technical efficiency and farm investment in term of net investment, therefore this hypothesis is partly accepted. As a result, policy interventions that stimulate any of the three factors can potentially have additional positive impacts through spillover effects on other factors, consequently, these farms' resilience to the impact of extreme weather events and climate change might be further improved.

Table 1: *Summary of the results*

Research question	Hypothesis	Conclusion
RQ1: What is the spatial pattern of crop insurance take-up?	**H1:** The intensity of insurance use has a spatial pattern, as farmers' insurance decision are influenced by the decisions of nearby producers.	Confirmed
RQ2: What are the factors that influence the farmers' crop insurance decision?	**H2:** Crop insurance level is influenced by the rate of fruit production and vegetable production in total crop production.	Partly confirmed
	H3: Crop diversification increases crop insurance usage.	Confirmed
	H4: Farm size impacts positively on crop insurance take-up.	Partly confirmed
	H5: Older and higher educated farmers are more willing to adopt crop insurance to reduce production risk.	Partly confirmed
	H6: Increasing financial performance encourages crop insurance purchase.	Rejected
RQ3: Does crop insurance take-up affect technical efficiency?	**H7:** Crop insurance take-up influences positively farms' technical efficiency.	Confirmed
RQ4: How to describe the interrelationship between crop insurance take-up, technical efficiency and farm investment?	**H8:** Crop insurance take-up, technical efficiency and investment interact positively.	Partly confirmed

Source: own composition

3.2. Policy implications

In view of these results, some recommendations could be made to improving farms' resilience to extreme weather events and climate change.

Firstly, the existence of spatial relationship in crop insurance usage between settlements can help both decision makers and insurance companies to expand the take-up of crop insurance, for example through the improved design of awareness-raising and marketing strategies.

Secondly, since the crop insurance take-up has a positive and significant impact on investment, policy interventions focusing on insurance use might also pay attention to investment to further enhance this impact, for example, differentiating insurance premium subsidies depending on whether there is an ongoing (or operating) investment that can be linked to weather-related risk management.

The third recommendation considers subsidies. This is related to the results of the research but is beyond the hypotheses tested. Subsidies have a significant role for crop insurance take-up, technical efficiency and farm investment. But it seems that in the concept of these factors, the targeted financial support is more effective than total subsidies including direct payments. Total subsidies increase crop insurance demand and investment. However, targeted subsidies provide a greater incentive to insure and invest than total subsidies. Premium support encourages crop insurance demand and investment subsidies stimulate investment more than total support. Furthermore, total subsidies reduce technical efficiency. This finding can help decision makers to further develop agricultural support schemes, for example, through the refinement of direct support schemes.

3.3. Limitations and directions for future research

The limitation of the research regarding to the first paper was data availability. In addition to the factors studied, other factors might also have an influence on insurance-take-up (e.g., income level), but only the data examined were available for all farms taking up subsidised insurance. The average farm size was the best available proxy for income level which referred to the amount of SAPS payments received. This subsidy represents a significant part of the income in case of crop producers. Furthermore, only subsidised crop insurance data were available in settlement level, there was not any information about the spatial distribution of non-subsidised crop insurance.

Regarding to the second paper, it did not examine the causality effects between efficiency and insurance demand, and it investigated the possible lagged effect of dependent variable only for the pooled model, not for the random effects probit model. Therefore, the causality effects were explored in the third paper using system of simultaneous equations. However, further research is needed to investigate the dynamic relationship between insurance take-up, technical efficiency and farm investment, since only average historical values were taken into account as proxy variables to willingness to insure and to willingness to invest.

3.4. New scientific results

The dissertation is based on three articles and aimed to explore the influencing factors of crop insurance take-up, and evaluate the effect of crop insurance purchase on technical efficiency and farm investment, and analyse the interrelationship between these three factors. The analysis was carried out using quantitative methods, such as Moran's *I* index, dynamic spatial autoregressive model, various probit models, DEA method with double bootstrap and system of simultaneous equations based on crop insurance data collected by Research Institute of Agricultural Economics (AKI), on utilised area data from the Integrated Administration and on FADN data.

This dissertation contributes to existing research in the field of risk management in crop production. Only a few results can be found in the literature regarding the spatial pattern of crop insurance usage. In the course of our research, we analysed the spatial pattern of premium subsidised crop insurance take-up using spatial econometric methods. This research is the first to provide the spatial analysis of farmers' crop insurance take-up at settlement level.

A large body of literature has investigated the determining factors of crop insurance demand. However, the research published in the second article, is the first, which studied the influencing factors of crop insurance demand among Hungarian crop farms for a time period that included the introduction of Hungarian National Risk Management System. It explored that farmers' characteristics, farm size, indebtedness rate and lagged insurance usage had a positive effect on crop insurance demand. However, concentration decreased crop insurance take-up. In addition, this research concluded that the two-scheme risk management system contributed significantly to the expansion of crop insurance demand.

Unlike previous studies, the second published article is the first to investigate the effect of crop insurance take-up on the technical efficiency of crop farming. It revealed that crop insurance demand had a positive effect on technical efficiency. Furthermore, the last article explored firstly the interrelationship between crop insurance take-up, technical efficiency and farm investment. It concluded that crop insurance usage stimulated both technical efficiency and farm investment, and crop insurance demand was encouraged by technical efficiency and farm investment, too.

This dissertation provides significant and consistent results in line with the previous empirical literature and draw up policy implications for decision makers, insurance companies and researchers.

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