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Risk management in crop farming

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Doctoral dissertation

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“The essence of risk management lies
in maximizing the areas where we have some control over the outcome while
minimizing the areas where we have absolutely no control over the outcome
and the linkage between effect and cause is hidden from us.”

(Peter L. Bernstein)

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1. INTRODUCTION

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 this 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, it is structured as follows. Chapter 2 provides a literature review, which presents an overview of risks and risk management strategies in the EU, and depicts the main features of Hungarian Agricultural Risk Management System. In addition, this chapter gives an insight into the influencing factors of crop insurance take-up, of technical efficiency and of farm investment based on scientific literature. Chapter 3 contains a short overview of methodology, including research questions, hypotheses and the description of methods and data applied in the papers. The papers are presented in the next three chapters. The results of the three articles 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. Chapter 7 presents an overview of the results achieved in the tree papers, followed by Chapter 8 providing a summary which concludes the doctoral dissertation and resumes the new scientific results.

2. LITERATURE REVIEW

2.1. Risk management in agriculture

The terms 'risk' and 'uncertainty' can be defined in different ways. Knight (1921) introduced the terminology of risk for measurable uncertainty and uncertainty to unmeasurable one. According to Hardaker *et al.* (2004), risk is defined by imperfect knowledge where the probabilities of the possible outcomes are known, in case of uncertainty the probabilities are not known. In line with common usage, uncertainty is imperfect knowledge and risk is uncertain consequence.

What is risk in agriculture? According to Miller *et al.* (2004), most farmers think about potential losses when they think about risk, and focus only on the adverse consequences. However, it is important to not lose sight of the potential reward associated with risk. Risk may be unavoidable, but it is manageable.

Huirne *et al.* (2000) and Hardaker *et al.* (2004) identify two major types of risk: business risk and financial risk. The aggregate effect of production, price, institutional and personal risk is business risk. Production risk comes from unpredictable weather and uncertainty about the performance of crops and livestock, e.g., through the incidence of pests and diseases. Prices or market risk is related to the uncertainty of price of inputs and outputs at the time that farmers have to make production decision. Governments are the source of institutional risk for farmers. Changes in the policy that affect farm production can have implications for profitability. People who operate the farm may themselves be the source of human or personal risk due to death of owner, divorce, prolonged illness, or carelessness by farm workers. In contrast to business risk, financial risk arises from the source and the method of financing the firm.

According to Harwood *et al.* (1999), risk management for individual farmers involves finding the preferred combination of activities with uncertain outcomes and varying levels of expected return. Similarly, Hardaker *et al.* (2004) describe risk management as a process to balance risks against possible rewards. Risk management can also be defined as the systematic application of management policies, procedures and practices to the tasks of identifying, analysing, evaluating, treating, monitoring and reviewing risk (ISO, 2009). Spiegel *et al.* (2020) have broaden the definition of risk management in the context of resilience. Their definition includes not only strategies to deal with shocks but also with long-term pressures on economic, environmental and social function of farms.

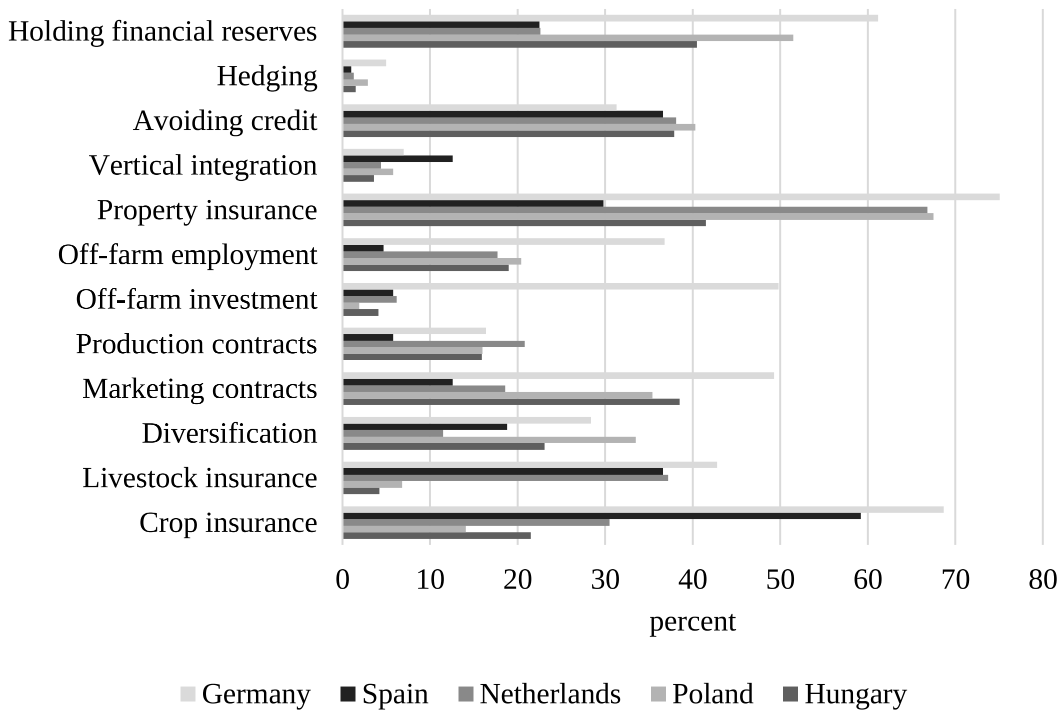
Huirne *et al.* (2000) distinguish two major categories of risk management strategies. in agriculture: on-farm strategies and strategies to share risk with others. On-farm strategies include collecting information e.g., about more productive technology and about marketing opportunities and market trends; avoiding or reducing risk exposure by adopting effective farm system monitoring and control procedures; selecting less risky technologies, e.g., crop production with irrigation; diversification by selecting a mixture of activities; flexibility referring to the ease and economy with which the farm can adjust to changed circumstances. Risk sharing strategies involve farm financing, such as the way of credit use; optimizing financial leverage; insurance take-up; contract marketing and futures trading.

According to OECD (2009), agricultural risk can be segmented into three layers. The first layer consists of ‘normal risk’ which are the losses or gains that are part of the normal business environment. They are frequent but cause relatively limited losses which farmers should themselves manage with for example financial assets management or off-farm work. The second layer includes risks that are more significant but less frequent. These risks can be managed by specific market instruments, like insurance or options. The third layer corresponds to the catastrophic risks, which generate very large losses with low frequency. This type of risk is more difficult to share through market mechanism, these can be managed through social safety nets and disaster reliefs.

2.1.1. Risk management strategies in the EU

Székely and Pálinkás (2009) surveyed agricultural producers about their risk perceptions and risk management strategies used in five EU Member States. The results of their survey are presented in Figure 1. Crop insurance demand was the highest in Germany and Spain between 2006 and 2007. Hungary was only the fourth from the five countries in this period regarding crop insurance demand. Hungarian farmers preferred property insurance, holding financial reserves, marketing contracts and avoiding credit to other risk management tools. Property insurance was also an important risk management instrument in Poland, Netherland and Germany. Holding financial reserves was a common tool among Hungarian, Polish and German farmers. Marketing contracts was important only in Hungary and Poland. However, avoiding credit is quite important for all the five Member States.

Figure 1: *Use of risk management instruments in the period 2006-2007*

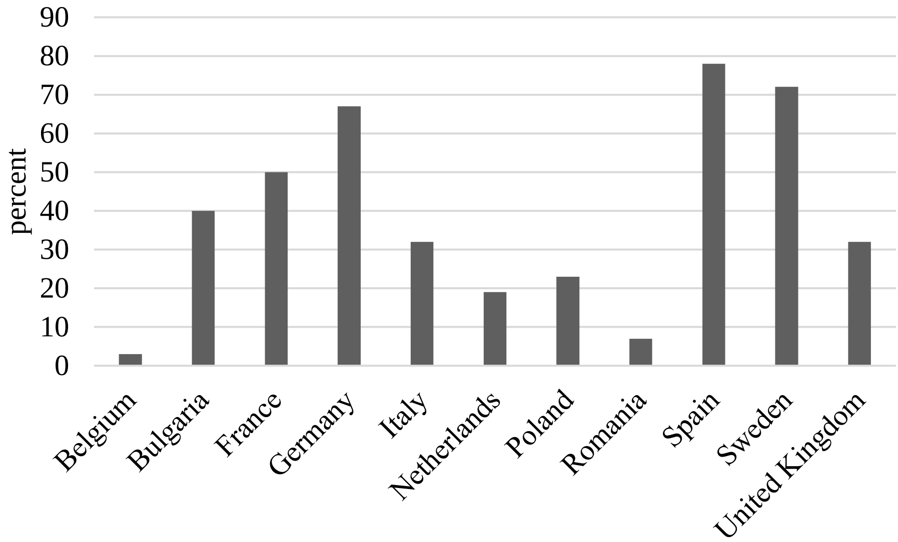


Source: Own edition based on Székely and Pálinkás (2009)

Regarding to the farm survey of Soriano *et al.* (2020) in the EU for the period 2014-2018, the most frequent used on-farm risk management strategies (used by above 40 percent of the farms) were: financial savings for hard times; low or no debts at all to prevent financial risks; working harder to secure production in hard time and implementing measures to prevent pests or diseases. Investment in technologies was applied only by 27 percent of the farms surveyed. Regarding to off-farm management strategies, the most popular tools (used by above 50 percent of the farms) were: member of a producer organisation, cooperative or credit union; learning about challenges in agriculture; access to a variety of input suppliers. However, only the 27 percent of the farms bought any type of agricultural insurance.

The farmers' perceptions of risk and resilience, including agricultural insurance demand, was investigated by Spiegel *et al.* (2019). They conducted farm survey in eleven case study regions across the EU and they obtained 1,152 producers in total. They found large differences in agricultural insurance usage (Figure 2), which is in line with the findings of Székely and Pálinkás (2009).

Figure 2: *Share of farms that purchased any type of agricultural insurance in the period 2014-2018*



Source: Own edition based on Spiegel *et al.* (2019)

According to Vroege and Finger (2020), there are various types of crop insurance. For example, single or multiple peril insurance that covers one or more specific risks, and yield insurance covering production losses caused by any peril. In addition, revenue insurance also exists. The most commonly applied crop insurance schemes are indemnity insurances that adjust losses based on physical damage.

Alternative insurance schemes are area-yield insurance and index insurance. The indemnities of area-yield insurance are based on crop yield in a region rather than the producers' yield (Miranda, 1991). The payoffs of index insurance are based on a widely available and objectively measured index. The value of the index is also independent of individual yield (Vedenov and Barnett, 2004). Both area-yield and index insurance eliminate adverse selection and moral hazard (Miranda, 1991; Vedenov and Barnett, 2004).

Vroege and Finger (2020) analysed 12 area-yield and index insurance in Europe and North America. They argued that a greater diversity of insurance options could strengthen the resilience of European farming system.

According to EC (2017), risk management instruments have become more important over time in the Common Agricultural Policy (CAP). Firstly, a risk management layer was introduced in the CAP with the 2008 Health Check. This layer provided targeted risk coverage instruments, such as subsidised insurance schemes and mutual funds for fruits, vegetables and wine producers. This option was removed with the 2013 reform. Instead, support for risk management was introduced in the second pillar for the period 2014-2020, which could provide financial contribution to insurance premiums, mutual funds and a newly introduced income stabilisation tool.

2.1.2. Hungarian Agricultural Risk Management System

Crop insurance for extreme weather events can play an important role in mitigating the financial implications of climatic change (Di Falco *et al.*, 2014). However, the demand for the crop insurance have been modest without subsidy in Hungary. In recent decades, the Hungarian government has attempted several initiatives in order to encourage farmers' self-care related to weather-based risk (Kemény *et al.*, 2010).

In the period 1996-2004 the government contributed to the agricultural insurance premiums paid by farmers by 30 percent (Bielza Diaz-Caneja *et al.*, 2009). Kemény *et al.* (2010) pointed out that despite the insurance premium subsidy, the number of farmers involved and the area insured did not change significantly. They argued that the natural hazards covered by crop insurance did not broaden, natural hazards such as drought, inland water and spring frost were not insurable. To deal with this issue, damage mitigation system (DMS) was introduced in 2007 which covered the most of the major weather risks in Hungary. Kemény *et al.* (2010) denoted that DMS did not bring much change due to low compensation. The payments covered only about 10-20 percent of all losses. Participation in DMS was voluntary between 2007 and 2008, while it was compulsory between 2009 and 2011, except for large farms and primary producers. The DMS fund was financed 50-50 percent by state support and farmers' contribution.

In order to increase the cover rate of the DMS a new two-scheme system was introduced in 2012, providing both damage mitigation and supported crop insurance schemes (Kemény *et al.*, 2012). The participation in the damage mitigation scheme is compulsory for all farms above a certain size[1] in hectares. Between 2012 and 2015 compensation was offered only if the overall losses at the farm level exceed 30 percent. This limit was reduced to 15 percent in 2016. Since 2017, this limit has applied to losses at cultivated crop level instead of losses at farm level (Péter *et al.*, 2020). The second scheme consists of crop insurance premium support for three types of insurance (‘A’, ‘B’, ‘C’). The participation in this scheme is voluntary. Under this scheme, the financial support could not exceed 65 percent[2] of the premium paid for the period 2012 and 2019. In 2020, the limit of financial support was raised to 70 percent from 65 percent. The three types of subsidised insurance cover different combinations of crops and natural hazards. The ‘A’ type (also referred as ‘all-risk’) insurance covers all the most important weather risks for the major arable and fruit crops. Since 2019, the ‘A’ type insurance has also been available for stone fruits. For the period 2012 and 2018, the ‘B’ type insurance addressed the major vegetable crops, minor fruit crops and some major arable crops, and covered only certain major risks. In 2019, the range of weather risks covered was expanded and the range of crops covered was slightly modified. Since that year, all the most important weather risks have been insurable by ‘B’ type insurance, but it has been available only for fruit crops and vegetable crops. Between 2012 and 2018, the ’C’ type insurance was open to all relevant crops for any damage not covered by insurance types ‘A’ and ‘B’. Since 2019, the ‘C’ type insurance has been available only for arable crops (Péter *et al.*, 2021; Péter *et al.*, 2020). Following the launch of the two-scheme risk management system farmers have had the option to cover weather risk by taking up premium subsidised or non-subsidised (traditional) crop insurance.

The system was broadened with the national hail damage mitigation system in 2018. This system covers the entire country with 986 soil generator (222 automatic and 764 manual) installed at the intersections of a 10x10 kilometre grid (NAK, 2021; Péter *et al.*, 2021). As a further development of the risk management system, crisis insurance scheme was introduced in 2021. The aim of this scheme is to reduce the fluctuation of farmers’ incomes caused by weather risks or other risks, such as market disturbances, falling prices or animal and plant diseases. The compensation is offered only if the income losses at the farm level exceed 30 percent (MÁK, 2020).

[1] Above 10 hectares for arable crops, above 5 hectares for vegetables and above 1 hectare for fruits.
[2]

2.2. Crop insurance

Crop production is sensitive to weather conditions and other hazards, therefore there is a potential demand for crop insurance. Crop insurance exists in several countries, but non-subsidised private insurance has mostly been limited to single-peril, such as hail insurance. The main difficulty is the high transaction cost associated with crop insurance market due to information asymmetries which makes insurance premiums too expensive, and therefore reduces the demand for crop insurance (OECD, 2009).

Private single peril crop insurance is available in the vast majority of EU Member States. Italy and Spain offer the largest programmes, which subsidise yield insurance premiums up to 65 percent, nevertheless the participation is low (e.g., in Italy is around 15 percent). Germany is the only of the Member States which offers multiple peril insurance without subsidies (Santeramo and Ramsey, 2017).

Subsidised crop insurance is available in Austria, Belgium, Croatia, France, Italy, Lithuania, Hungary, Malta, the Netherlands, Portugal and Spain (Santeramo and Ramsey, 2017).

The non-existence of private all-risk crop insurance was caused by two types of market failure: adverse selection and moral hazard, which arise from asymmetric information between insurers and farmers (Knight and Coble, 1997). Adverse selection arises in crop insurance when differences in riskiness of different farmers crop production are not fully observed by the insurer (Wright and Hewitt, 1994). Moral hazard occurs when the insured farmer’s optimal decision may change as a result of taking out insurance (Quiggin *et al.*, 1993). However, Wright and Hewitt (1994) argued that the explanation of the failure of all-risk insurance is that all-risk crop insurance is worth less than what it costs, if full costs are covered by insurance premiums in the long run.

In general, agricultural producers are risk averse; farmers who are more risk averse tend to perceive greater probabilities of farm losses occurring (Menapace *et al.*, 2012). However, more farmers perceive themselves as more risk-loving (or less risk averse) than other farmers based on self-assessment of risk preferences (Spiegel *et al.*, 2019).

Ramaswami (1993) decomposed the impact of crop insurance on input use into a risk reduction effect and a moral hazard effect. The former stimulates the insured farmer to seek greater expected revenue, the latter encourages the insured farmer to decrease the input usage.

2.2.1. Influencing factors of crop insurance take-up

Farmers purchase crop insurance for three reasons: risk-aversion, positive expected benefits (e.g., subsidy), possibility of adverse selection (Just *et al.*, 1999). Hazell *et al.* (1986) assumed that the main objective of crop insurance was farm income stabilization. However, other positive externalities arise related to welfare and resource use due to crop insurance take-up.

According to the expected utility theory (EUT), given a fair premium, risk averse decision makers are predicted to purchase insurance by which the indemnity equals the loss (Zweifel and Eisen, 2012). Babcock (2015) pointed out that farmers' crop insurance demand was not generally consistent with EUT. Therefore, he suggested to apply the cumulative prospect theory (CPT) to explain farmers' purchase decision for the reason that for these farmers losses were felt if the indemnity received did not cover the premium paid.

The demand of crop insurance is influenced by several factors. According to Nieuwoudt *et al.* (1985) and Hazell *et al.* (1986), the participation in crop insurance program is influenced by the farmer's utility function of income, his current income, his subjective frequency distribution of future income and the change of it generated by the insurance subscription, such as insurance premium and insurance compensation.

Makki and Somwaru (2001) analysed maize producer's decision to participate in crop insurance programme and their choice of insurance contracts in Iowa for the period 1995-1999. They found that the important factors affecting the decision included the availability of revenue insurance products, the level of risk, the premium rate, the level of subsidy and the design of the contract.

Baráth *et al.* (2017) categorised the determinants of crop insurance demand into groups of variables: risk management substitutes, the farmer's risk perception and attitude, farm risk exposure, and farm characteristics (e.g., size and economic performance). Finger and Lehmann (2012) distinguished six main groups of influencing factors: farm and farmer characteristics (e.g., farm size, farmers' age and education), the composition of farm income (e.g., the rate of off-farm income), production risk (e.g., local climate conditions), employed production practices (e.g., irrigation), the monetary value of farm production (e.g., expected yield and output price levels) and the price of insurance premium (e.g., subsidised or non-subsidised).

This section offers an overview about these influencing factors based on previous literature.

2.2.1.1. Farm size

Most research dealing with insurance demand pays special attention to farm characteristics, such as farm size. First, an overview of these results follows.

Barnett *et al.* (1990) investigated the role of farm size in participation in crop insurance among U.S. wheat producers. They found positive relationship between farm size and crop insurance take-up. They argued that the agent who sold crop insurance received a commission which was based on the percentage of the total premium collected. Larger farms might insure more acres which generated higher commissions, thus the net delivery costs per unit for crop insurance were relatively lower for large farms compared to small farms. The model of Goodwin (1993) also revealed positive effect of farms size on crop insurance demand, namely, larger farms were more likely to purchase insurance. Enjolras and Sentis (2011) found evidence of the impact of farm size on insurance usage of French farms from the period 2003-2006. Their results suggested that insurance was subscribed by larger farms because it was too expensive for smaller farms. Di Falco *et al.* (2014) also detected positive relationship between farm size and insurance usage, explained by those farmers who invested more resources in land had a greater incentive to hedge against bad environmental conditions. Positive effect of farm size on crop insurance demand was also found by Baráth *et al.* (2017), Calvin (1992), Enjolras and Sentis (2008), Di Falco *et al.* (2014), Sherrick *et al.* (2004).

Type of business is closely related to farm size. In general, corporates operate in a larger area than individual farms. According to Goodwin (1993), type of business also has on impact on crop insurance demand. Corporations are found to be more likely to use crop insurance to manage weather-related risks.

It can be concluded, that researchers for different reasons but agree on the positive effect of farm size on crop insurance demand. The main reasons in favour of larger economies are the higher commission expected by the agent, the high premium which is affordable only by larger farms and the greater incentive to hedge against extreme weather conditions induced by greater land.

2.2.1.2. Age and education

Regarding to the literature, the role of the farmers age and education is ambiguous. Several researchers investigated the effect of these two factors, but there is no consensus on the results.

Sherrick *et al.* (2004) surveyed about 3000 farmers in Illinois, Iowa and Indiana who operate at least 160 acres. They found that the likelihood for crop insurance usage was higher for older farmers compared to younger farmers. They argued that insurance users are more experienced which leads to greater precision in risk assessment. This finding is in line with the results of Finger and Lehmann (2012) who studied the determinants of hail insurance use of Swiss farmers in the period 1990-2009. They demonstrated that insurance users were usually older and better educated farmers. However, Calvin (1992) showed that older farmers were less likely to purchase crop insurance than younger counterparts. She argued that older farmers might be less risk averse.

Contrary to the presumption that experienced and more educated farmers would be more interested in insurance coverage, Enjolras and Sentis (2008) did not find any significant effect of education on insurance usage, except in case of farmers with university course, who are less likely to insure than farmers with no or other kind of education. In addition, they found negative relationship between farmers age and crop insurance demand which is in line with the findings of Calvin (1992). Wu (1999) also reported nonsignificant effect of education, but his model revealed significantly positive influence of farming experience on crop insurance demand among maize producer in the US in 1991.

2.2.1.3. *Yield risk*

The effect of yield risk in crop insurance usage was investigated in various aspects by several researchers. The main results are as follows.

Shaik *et al.* (2008) studied the demand for crop revenue and yield insurance by eliciting subjective probabilities from maize and soybean producers on price and yield variability in Nebraska, Indiana and Mississippi. Result suggested that high yield producers would be less likely to use crop insurance. In addition, expected price also has a negative effect on crop insurance demand which increases when expected prices are low. In turn, Horowitz and Lichtenberg (1993) found that insurance usage was more likely in areas with higher maize yields among farmers in the U.S. Midwest, because of the size of potential loss was greater. However, the higher yields from alternative crops discourage crop insurance demand indicating that crop diversification is more profitable than crop insurance usage.

Cabas *et al.* (2008) modelled entry and exit decision of soybean farmers in Ontario for the period 1988-2004. They showed that exit decision might be caused by an increase in the average county yield in the previous crop year. In addition, yield variability is significant for both new entrants and dropouts.

According to Enjolras and Sentis (2011), the risk exposure has a determining role in crop insurance take-up. The highest risk farms are more likely to purchase insurance. In addition, the insurance decision is influenced by the past amount of claims received. The higher past temperature and higher past rainfall also make the farmers more willing to undertake crop insurance (Di Falco *et al.*, 2014).

The researchers disagree on the role of high crop yield on crop insurance demand, but they agree that an increase in yield variability encourages insurance usages.

2.2.1.4. *Location*

Despite the close relationship between yield risk and location, there are only few studies exploring the role of location in crop insurance demand.

Tobler's First Law of Geography says that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). The effect of location on crop insurance take-up was investigated by Adhikari *et al.* (2010). They studied spatial heterogeneity in farmers' decisions about to purchase of yield-based or revenue-based crop insurance in the three major maize producing states in the US for the period 1999 to 2007. Spatial patterns were found in insurance choice decision according to Moran's *I* statistics, pointing out the relative influence of trusted sources, such as nearby producers, on insurance decision.

Woodard *et al.* (2012) analysed the loss-ratio patterns in the US maize insurance market with spatial econometric model. They results indicated systematic geographically related misratings which likely had insurance demand implications. Chen *et al.* (2020) examined the scale, pattern and fiscal implications of misrating the premium in the federal crop insurance program. Results demonstrated that about 40 percent of the counties displayed misrating. The distribution of misrating had a significant pattern of positive global spatial autocorrelation, suggesting the existence of regional clusters of premium rate mispricing.

Only one of the three research presented above investigated the effect of location on crop insurance decision. That study demonstrated significant spatial pattern in insurance demand. However, the other two research examined the spatial distribution of misratings which could have insurance demand implication. Additional studies to understand more completely the role of location are required.

2.2.1.5. Insurance premium

The high insurance premium is one of the most important disincentives to take out crop insurance. Several studies confirmed the negative role of high insurance premium.

Barnett *et al.* (1990) investigated at first the price elasticity of demand for crop insurance regarding US wheat producers in 1987. Results suggested that an increase in insurance premiums discouraged the participation in insurance schemes, which is in line the findings of Goodwin (1993), who investigated county-level data of maize producers in Iowa for the period 1985 to 1990. Ginder *et al.* (2009) identified the price of insurance as the most influential factor in crop insurance purchasing decision among farmers in northern Illinois based on a mail survey. Garrido and Zilberman (2008) also showed that insurance policies with a large insurance premium in relation to total liability were not attractive to producers.

Hungarian farmers are also price sensitive. The difference in the insurance premium rates between arable, fruit and vegetable crops influences crop insurance demand in Hungary. The relative high insurance premiums for fruit crops compared to arable and vegetable crops reduce the willingness of fruit farmers to purchase insurance (Keményné Horváth *et al.*, 2017). Enjolras and Sentis (2011) also depicted that specialisation of the farm had a significant effect on insurance use, namely, vegetable specialised farms were more exposed to weather risks, therefore these were more willing to get coverage.

2.2.1.6. Insurance history

Researchers are of the similar opinion on the impact of insurance history on crop insurance take-up, namely, previous year insurance usage encourages the crop insurance demand in the current year.

Serra *et al.* (2003) showed that the lagged value of crop insurance expenditure was likely to be positively correlated with farmers' risk aversion, thereby it encouraged the demand for crop insurance. Enjolras and Sentis (2008, p. 12) observed a fidelity to insurance, "once a farmer is insured, he remains insured". Farmers who have already purchased crop insurance are more willing to insure again. This is in line with the findings of Boyd *et al.* (2011), those farmers who purchased crop insurance last years, are likely to purchase it again the current year.

2.2.1.7. Diversification

Diversification could be understood in many different ways. In this section the impact of income diversification, production diversification and crop diversification on crop insurance usage are summarized.

Knapp *et al.* (2021) investigated the relationship between seven different kind of income diversification and crop insurance take-up among Swiss fruit growers. They concluded that on-farm diversification, such as crop diversity, effected positively on insurance usage; off-farm diversification, like off-farm income, influenced negatively the insurance take-up.

Income diversification: Off-farm income diversifies a farmer's income and provides income stability, thereby it reduces the probability of insurance purchase (Barnett *et al.*, 1990; Calvin, 1992).

Production diversification: The result of Mishra *et al.* (2004) showed that there was a significant positive relationship between enterprise diversification and crop insurance take-up. They argued that production diversification and private risk management strategies were complements. In contrast, Calvin (1992) treated production diversification as a substitute for crop insurance. Her model revealed that diversifying into livestock had negative impact on crop insurance take-up.

Crop diversification: Enjolras and Sentis (2008) found that insured farms had more diversified crop portfolio compared to non-insured farms. They concluded that combining these risk management strategies is a sign of risk aversion. In turn, Calvin (1992) pointed out, that crop diversification reduced farm income risk and therefore decreased the demand for crop insurance. This result is in line with the finding of Di Falco *et al.* (2014) and Goodwin (1993) that farms growing more crops are less likely to purchase crop insurance. Thus, crop diversification can be a substitute for crop insurance to deal with the financial impact of weather risks.

The role of income diversification is slightly clear, researchers agree that income diversification discourages crop insurance usage. In contrast, production diversification and crop diversification can have both positive and negative influence on crop insurance take-up which means further investigation is required.

2.2.1.8. Production practices

Production practises also can influence crop insurance decision. This section gives an overview about the role of chemical input usage on crop insurance demand.

Smith and Goodwin (1996) showed that Kansas dryland wheat farmers who used chemical inputs more intensively were less likely to take out crop insurance. They argued that the more intense cultivation practices decreased the probability and size of losses. In addition, moral hazard incentives lead insured farmers to decrease the application of chemical inputs. These results are in line with Serra *et al.* (2003) who investigated insurance demand among Kansas farmers over the period 1993-2000. They found that the application of chemical inputs reduced the expected return from crop insurance, therefore reduced the crop insurance demand.

In turn, Horowitz and Lichtenberg (1993) argued that fertilizer and pesticides might be risk-increasing inputs. Results suggested that crop insurance purchase increased chemical usage of maize farmers in the US Midwest. Möhring *et al.* (2020) found positive and significant relationship between pesticide use and crop insurance demand using data of French and Swiss farms for the period 2009-2015. The authors pointed out that pesticide expenditures would be 6 to 11 percent lower without crop insurance. Similarly to Horowitz and Lichtenberg (1993), they also highlighted the risk-increasing effect of pesticides. Di Falco *et al.* (2014) also presented that farm using large quantities of inputs was more likely to purchase crop insurance. They explained this result by that higher expenditure on inputs (plant protection, fertilisers and irrigation water) increased the variance of revenues which enhanced the crop insurance take-up.

The main issue is whether the use of chemicals increases or decreases the production risk. Based on the literature, it is a controversial topic which needs further investigations.

2.2.1.9. Subsidies

The effect of subsidies on crop insurance demand is also a commonly researched topic, but mixed results have been obtained about the role of subsidies. Premium subsidy is found as an incentive in most cases, but income support mostly decreases the probability that farmers take out crop insurance.

Garrido and Zilberman (2008) found that premium subsidies clearly stimulated purchasing insurance among Spain farmers between 1993 and 2004. They pointed out that higher crop insurance premium was associated with lower insurance demand and, thereby they identified premium subsidies as leading factor increasing crop insurance participation. This is in line with the findings of Makki and Somwaru (2001) who also showed that premium subsidies encouraged the participation in crop insurance program. However, they highlighted that lower premium rate through premium subsidies might also create an incentive to assume more risk. In turn, Serra *et al.* (2003) found that increasing participation in crop insurance program through premium subsidies or premium discounts would have difficult among farmers in Kansas during the 1990s. They explained this result by the inelastic relationship between crop insurance purchase and premium rates.

Finger and Lehmann (2012) examined the effect of direct payment on crop insurance demand. They showed that the larger share of direct payment for total farm revenue, the less attractive was insurance as risk management tool. They argued that income support is a substitute for agricultural insurance. This explanation was based on the study of Hennessy (1998), who examined the effect of agricultural income support on production. He pointed out that income support reduced the variability of total farm income, thus it had an insurance effect. The results of Finger and Lehmann (2012) are in line with the findings of Koundouri *et al.* (2009), who investigated the impact of decoupled payment on Finnish farmers' risk attitude. They found that an increase in the non-random part of farm income generated by the policy change after EU accession decreased risk aversion. However, Baráth *et al.* (2017) pointed out that subsidies might positively influence farms insurance demand in an institutional environment characterized by farm budget constraints. They found that subsidies might increase crop insurance participation by relaxing farm budget constraints.

2.2.1.10. Economic and financial performance

Farmers' financial wealth also has to be considered when examining insurance decision (Harrington and Niehaus, 2003). In the literature, several economic and financial indicators have been taken into account in connection with crop insurance demand. A brief overview follows.

According to Baráth *et al.* (2017), economic performance (measured by profit margin and total factor productivity) effected positively on insurance demand, suggesting the presence of budget constraints on Hungarian farms.

However, Enjolras and Sentis (2011) showed that turnover and return on capital employed (ROCE) played a negative role in crop insurance take-up. They argued that "the more profitable the farm was, the less need there is to hedge" (Enjolras and Sentis, 2011, p. 5). The role of return on equity (ROE) on crop insurance purchase was found nonsignificant by Enjolras and Sentis (2011) and Enjolras and Sentis (2008).

Calvin (1992) investigated the role of debt to asset ratio (also known as financial leverage) on crop insurance demand. She found that financial leverage increased the probability of purchasing crop insurance, because farmers with low debt to asset ratio were more likely to be able to borrow to cover any cash-flow problems in years with low revenue. Similarly, Sherrick *et al.* (2004) found positive relationship between leverage and crop insurance usage, since greater financial risk induced stronger demand for insurance. Contrary to their previous expectations, the models of Enjolras and Sentis (2011) did not reveal any significant effect of financial leverage on crop insurance demand. They concluded that this result is came from the specificities of French context, i.e., the government could directly help the most affected farms regardless of crop insurance take-up.

2.2.1.11. Investment

The role of investment in crop insurance demand is not a commonly researched topic. There have been only very few results in this area which indicates the need for further examination.

A comprehensive survey was conducted by Lefebvre *et al.* (2014) who investigated the farmers' intention to invest in the period 2014-2020. They found that farmers from the EU who are intending to invest, were more likely to have positive attitudes towards innovation and to follow good farm management practices, such as having agricultural insurance or obtaining professional advice.

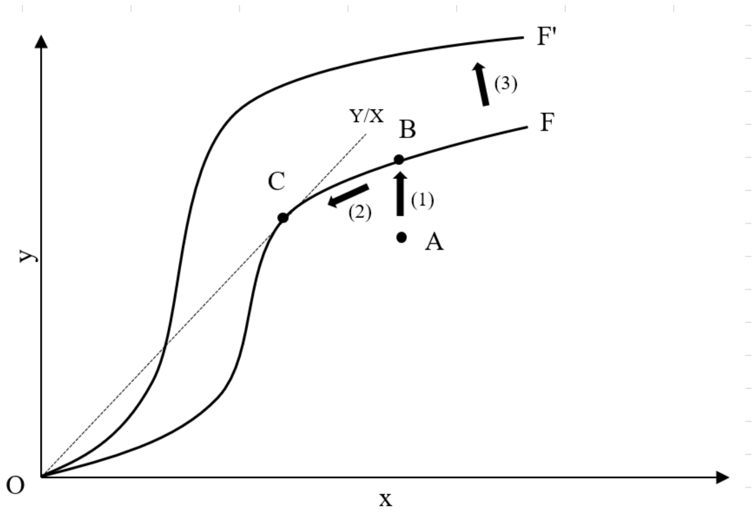
2.3. Technical efficiency

Agricultural productivity and efficiency are at the centre of many research related to competitiveness and sustainable development. Productivity is often studied, because increased productivity leads to better allocation of scarce resources. Thus, it results in higher national income by virtue this reallocation, by more efficient use of inputs and by reallocating the surplus to other activities (FAO, 2017).

„Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use" (OECD, 2001, p. 12). Agricultural productivity is based on two components: type and quality of inputs used in the production process; and how well these inputs are combined. The first component refers to the production technology, the latter means the technical efficiency of the production process (FAO, 2017). Farrell (1957) defines a farm's overall efficiency as the combination of technical efficiency and allocative efficiency. The former measures a farm's success in producing maximum output, given a set of inputs; the latter refers its success in choosing an optimal set of inputs. According to Bojnec and Latruffe (2009), technical efficiency is a proxy for farm performance, which refers to the ability of farms to use the best practice in relation to input and output quantities.

Figure 3 presents an illustration of technical efficiency regarding one input and one output. The production frontier (OF) shows the relationship between input and output; it represents the maximum output achievable from each input level at current state of technology. Technically efficient farms operate on the frontier, like points B and C. Technically inefficient farms produce under this frontier, such as point A (Coelli *et al.*, 2005). Figure 3 also demonstrates three possible ways to increase productivity. Firstly, farm can increase their productivity by improving technical efficiency. Secondly, productivity can be improved by exploiting economies of scale which can be identified by the scale elasticity[3] having a value at least one. Thirdly, increase in productivity can refer to technological change which results in an upward shift of the production frontier (OF') (Latruffe, 2010).

Figure 3: *Production frontiers and technical efficiency*



Source: Coelli *et al.* (2005) and Latruffe (2010)

Improvement of technical efficiency is necessary as regards the limited availability of natural resources, such as land and water, and given the need to limit the environmental footprint of agricultural production (FAO, 2017). Astier *et al.* (2012) highlighted that sustainability assessment also needed to focus on improving current system, particularly in the context of natural resource management.

Soriano *et al.* (2020) pointed out that improvement in technical efficiency is also contributes to mitigate farms' risk. They found that farmers preferred on-farm risk

[3] Scale elasticity is calculated as the ratio of proportionate increase in output to the proportionate increase in all inputs.

management strategies like improved management and economic efficiency to risk-sharing strategies to deal with future challenges. In addition, farmers identified efficiency increase (technology, specialisation, better management) as one of the most important strategies to cope challenges in the future. Technical efficiency improvement can also affect farms' resilience to the impacts of extreme weather events and climate change.

2.3.1. Influencing factors of technical efficiency

Studies focusing on the determining factors of technical efficiency at farm level, distinguish three groups of variables: farm characteristics (e.g., farm size) and technology employed; location and environmental variables; human capital variables (Latruffe *et al.*, 2004).

This section presents an overview about these determining factors based on previous research.

2.3.1.1. Farm size

Most research investigating the determinants of technical efficiency also examines the role of farm size in technical efficiency. Hall and LeVeen (1978) pointed out that larger farm could achieve economies of size due to spreading fixed cost over more land and output, getting volume discounts for purchased inputs or achieving greater market access. Wilson *et al.* (1998) also found positive relationship between farm size and technical efficiency while investigating UK potato producers. They also explained this result by size economies, i.e., larger farms had a potential for greater output with a given set of labour and machinery. This result is confirmed by Latruffe *et al.* (2004) who investigated technical efficiency among Polish crop and livestock producers in 2000. They found that the larger farms were more efficient for both specialisations. Thus, they concluded that farm size increasing policy measures might have beneficial effects on efficiency. Bojnec and Fertő (2013) examined technical efficiency among Slovenian farms for the period 2004-2008. They showed that economic farm size had a positive impact on technical efficiency, but this impact declined with increasing farm technical efficiency. Thus, farms should use innovative approaches to identify an optimal farm size. Balcombe *et al.* (2008) also found positive association between technical efficiency and farm size among rice farms in Bangladesh. They investigated farms which transplanted their crop following manual cultivation and did not use supplementary irrigation.

In turn, O'Neill and Matthews (2001) found negative relationship between farm size and technical efficiency among Irish farmers over the period 1984 and 1998. They argued that larger farms were under less income pressure to optimize their resource usage.

2.3.1.2. Age and education

The role of human capital, such as age and education are commonly examined in the context of efficiency, but the results are ambiguous for age. However, the role of education in technical efficiency is unambiguously positive.

Mathijs and Vranken (2001) analysed technical efficiency among Hungarian and Bulgarian farms in 1998. They found that age had a positive impact on technical efficiency among Hungarian crop farms, and it had a negative effect among Bulgarian crop farms in case of family farms, but age was not significant for corporate farms. The positive impact of age on technical efficiency could be argued "that older farmers are more experienced and they can use their knowledge to use inputs more efficiently" (Mathijs and Vranken, 2001, p. 4). The negative effect of age can be explained by the reduced ability to work (Mathijs and Vranken, 2001) or by unwillingness or inability to adopt technological innovations by older farmers (Herdt and Mandac, 1981).

Dessale (2019) also found positive effect of age on technical efficiency. He investigated Ethiopian wheat-growing farmers using cross-sectional household data of 2016-2017 main harvest cropping season. His result suggested that age positively influenced technical efficiency, explained by their increased farming experience. Positive impact of managers' age on technical efficiency was also revealed by O'Neill and Matthews (2001) and Nowak *et al.* (2016). Nowak *et al.* (2016) studied the technical efficiency of the EU Member States' agriculture between 2007 and 2011. Age of the manager is found to positively influence technical efficiency, since experience in the management of agricultural production could often substitute the formal education.

In turn, Wilson *et al.* (1998) found negative relationship between farm experience and technical efficiency among UK potato producers. They argued that farmers with fewer years of experience were more aware of current technology. In addition, Balcombe *et al.* (2008) showed that older farmer were more technically inefficient. They argued that older farmers were more conservative and less receptive to new technology and practices than younger counterparts.

Regarding to education, based on the findings of Dessale (2019), technical efficiency is positively associated with education, because more educated farmers have the ability to use information from various sources more effectively and are able to apply new farming practices that would increase outputs. Farmers with agricultural education are more technically efficient than their non-educated counterparts (Latruffe *et al.*, 2004). Mathijs and Vranken (2001) also found that education positively influenced technical efficiency among Hungarian and Bulgarian family farms. They argued that farmers with higher education might have more skills to manage their farm more efficiently. Balcombe *et al.* (2008) and Tiedemann and Latacz-Lohmann (2012) also reported positive relationship between technical efficiency and education.

2.3.1.3. Diversification

Diversification is a common risk management strategy to reduce income volatility. However, more specialised farms can achieve higher income due to the more focused farm management and scale economies (Kovács, 2009).

Income diversification: Off-farm income increases technical efficiency and helps farms to stay alive by giving the opportunity to redeploy labour outside the work season and by providing opportunity to earn additional income that can be invested in farm modernisation and growth (Bojnec and Fertő, 2013). In turn, Goodwin and Mishra (2004) found that intensive participation in off-farm labour markets decreased on-farm efficiency, moreover, the more efficient farmers tend to supply less labour to off-farm employment alternatives then the less efficient counterparts. Negative effect of off-farm labour on technical efficiency was also found by O’Neill and Matthews (2001). As they explained this result, the farmer with off-farm work had less time to deal with practical tasks of managing the farm efficiently.

Production diversification: Bojnec and Latruffe (2009) found that specialisation had a positive impact on technical efficiency among Slovenian individual farms during the transition to a market economy and before accession to the EU. An explanation for this result is that more specialised farm might be more efficient because farmers could focus their management efforts on fewer activities. Mathijs and Vranken (2001) also found that specialised crop farms were more technically efficient among Bulgarian crop producers, but their model revealed insignificant coefficient for specialisation in case of Hungarian crop farms.

In turn, Lazíková *et al.* (2019) found, that production diversity was an important factor to improve technical efficiency among Slovakian agricultural holdings. They pointed out that most of farms were focused on the mixed (crop and animal) production, and they highlighted that production diversity is one of the most important factors of sustainable agriculture.

2.3.1.4. Subsidies

According to the literature, subsidies also may have an influence on technical efficiency. Theoretically, subsidies may have both positive and negative impact on technical efficiency. On the one hand, subsidies might increase technical efficiency by providing the necessary financial means to keep technologies up to date or to invest in efficiency improvement (Zhu and Lansink, 2010). On the other hand, subsidies might reduce farmers' effort and thus reduce their technical efficiency (Bojnec and Latruffe, 2009). On the basis of extensive literature review, Minviel and Latruffe (2016) found that subsidies commonly influenced negatively farms' technical efficiency.

Zhu and Lansink (2010) investigated the impact of subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden for the period 1995-2004. The share of total subsidies in total farm revenues is found to negatively influence the technical efficiency in all the tree countries, through the income and insurance effect. Bojnec and Fertő (2013) and Bojnec and Latruffe (2009) also found that subsidies decreased technical efficiency due to reducing farmers' effort.

Lazíková *et al.* (2019) showed that CAP payments did not play a significant role regarding the technical efficiency of the agricultural holdings. They concluded that existing CAP subsidies did not motivate the farmers to increase their technical efficiency.

Nowak *et al.* (2016) investigated the role of investment subsidies in technical efficiency. They reported that investment subsidies encouraged technical efficiency, because investment subsidies enabled the modernization of the farms and the improvement of their competitive position in the market and improved the effectiveness of the management.

However, investment subsidies are part of total subsidies, the effect of investment subsidies and total subsidies seem to be different on technical efficiency. A significant proportion of total subsidies is income support which might reduce farmers' effort. In contrast, investment subsidies may improve technical efficiency due to facilitating modernization.

2.3.1.5. Crop insurance take-up

Based on the previous literature, the impact of crop insurance take-up on farms' technical efficiency has not been researched explicitly so far.

According to Shaik (2013), with crop insurance farmers reduce weather risks and they are willing to adopt innovative and efficiency enhancing production technologies which they would not willing to adopt, if they face more risk due to the absence of crop insurance. Carter *et al.* (2016), based on a theoretical approach, also highlighted that index insurance could, in the right environment and done in the right way, encourage the adoption of improved technologies.

Cornaggia (2013) demonstrated positive correlation between crop insurance take-up and productivity measured by crop yield, and this correlation was stronger for group-performance-based instruments than individual-performance based instruments, which could reflect the existence of moral hazard. The result is explained by that "risk management is associated with greater productivity, an intermediate channel through which risk management could affect firm value" (Cornaggia, 2013, p. 20).

Vigani and Kathage (2019) arrived at the opposite result investigating the impact of four risk management strategies (crop insurance, diversification, variety, contract) and the combinations of them on total factor productivity (TFP) among Hungarian and French farms between 2010 and 2013. The vast majority of the significant risk management portfolios found to have a negative impact on TFP in both countries. The negative impact is explained by the fact that risk management represents a net cost to farm, subtracting resources from agricultural production and consequently, decreases productivity. This is in line with the findings of Baráth *et al.* (2017) who argued with moral hazard, i.e., producer might change production practices after purchasing an insurance contract.

Similar negative result were obtained by Brick and Visser (2015) who studied small-scale and subsistence farmers in South Africa. Their result suggested that "risk-averse individuals were more likely to opt into traditional agriculture (reflected as traditional seeds in the experiment) and were less likely to use modern farming inputs that require financing (high-yield varieties) despite the availability of insurance" (Brick and Visser, 2015, p. 383) in developing countries.

Despite the previous significant positive and negative results, Tong *et al.* (2019) did not find any significant relationship between adaptation of crop insurance and technical efficiency among Chinese rice producers in 2017 probably due to moral hazards.

2.3.1.6. Investment

Investment is the basic way to increase efficiency. However, not every investment leads to increased efficiency entailing the phenomenon of overinvestment (Pawłowski *et al.*, 2021).

Pawłowski *et al.* (2021) investigated the technical efficiency for different overinvestment groups in Poland for the period 2004-2015. They found that underinvested farms were the least efficient. The highest efficiency is achieved by the relatively and absolutely overinvested farms, explained by the necessity of maintaining the level of tangible assets.

Mathijs and Vranken (2001), in contrast with the expected result, found that the previous year's investment decreased efficiency for Hungarian family farms. However, investment mostly increases technical efficiency, they argued that crop farms invested in livestock rather than crop production.

2.3.1.7. Other influencing factors

In the literature, several other factors have been also investigated, such as risk attitude, financial leverage, integration, soil quality, weather conditions and professional advice. An example of each factors listed above follows.

Risk attitude: Risk attitude of farm manager may have an impact on technical efficiency. Tong *et al.* (2019) found that most Chinese rice producers were risk averse which made them less efficient in input usage, explained by the overuse of inputs to make up for possible losses.

Financial leverage: Ratio of debt to assets is found to have a positive impact on technical efficiency, suggesting that farmers who are borrowing are better managers (O'Neill and Matthews, 2001).

Integration: Latruffe *et al.* (2004) showed, that the degree of market integration, defined by the ratio of total revenue over total output, had a positive impact on technical efficiency. Their result suggested that more commercially oriented farms are more technically efficient. They concluded that Polish farms which produced mainly or exclusively for their own needs "might stay in the vicious circle of low technical efficiency and technological backwardness" without market integration (Latruffe *et al.*, 2004, p. 9).

Soil quality: The soil quality influences positively technical efficiency, as expected (Latruffe *et al.*, 2004; Nowak *et al.*, 2016; Tiedemann and Latacz-Lohmann, 2012). Moreover, Latruffe *et al.* (2004) pointed out, that soil quality impacted positively technical efficiency not only for crop farms but also for livestock producers, because feed is mostly produced on-farm.

Climate change and weather conditions: According to IPCC (2014), increasing temperature and extreme rainfall patterns may influence significantly agricultural output. Moreover, climate change and weather conditions also may have an impact on technical efficiency. Vígh *et al.* (2018) found that an increase of temperature and perception influenced positively technical efficiency in the seeding and vegetative periods, but temperature increase reduced technical efficiency during the generative phase of crop production among Hungarian arable farms for the period 2002-2013.

Professional advice: Trust-, credibility- and empathy-based consultation between agronomist and farmer facilitate farmers' transformation to more sustainable best management practices (Ingram, 2008).

2.4. Investment

Generally, investment in agriculture is related to modernisation and technological upgrade, thereby playing a key role in improving farms' competitiveness and increase their resilience in surrounding, such as price volatility and climate changes (Wieliczko *et al.*, 2019). Spiegel *et al.* (2019) indicated that about half of arable and perennials crop producers invested in technologies (e.g., irrigation or hail nets) to control environmental risks in the EU.

Taking drought as an example, building the agricultural sector's resilience to drought will require improved management of increasingly unpredictable water resources and investments that will improve the sector's capacity to adopt to drought in long-term (OECD/FAO, 2021). Farm-level adaptation strategies, such as construction of water-saving irrigation system and soil improvement also can contribute to adaptation to drought.

2.4.1. Influencing factors of investment decision

In the literature, there are only few studies focusing on influencing factors of investment in agricultural sector. One of these studies is conducted by Lefebvre *et al.* (2014), who examined famers' investment decision. They surveyed 780 farm-households in six EU Member States (Czech Republic, Germany, Spain, France, Italy and Poland) to investigate the farmers' intention to invest in the period 2014-2020. Their study contributes to understanding investment patterns among EU farms, focusing on investments in land, buildings, machinery and equipment, training and production rights. They found that more than half of the farms intended to invest in the period 2014-2020, and the main purpose was to invest in machinery and equipment. The authors underlined that the main benefits expected from the investment were development in working conditions on the farm and improvement in production quality.

This section presents an overview about factors influencing farms' investment based on previous research.

2.4.1.1. Farm size

Based on previous literature, farm size is one of the drivers of investment. However, previous studies also suggest there is some ambiguity on the effect of farm size on farm investment.

Olsen and Lund (2009) investigated the incentives of investment among Danish farms in 2008 via survey. They measured farm size by standard gross margin; they also explored that farm size effected positively on investment decision. An explanation of this result is that larger farms had a wider portfolio of investments and they might be better in utilizing economies of scale and scope. LaDue *et al.* (1991) stated that farms making no investment were most likely be small farms; midsized farms were more likely to make only replacement investment; large farms were more likely to expand.

Niavis *et al.* (2020) surveyed Greek arable and orchard farms in 2019 regarding to investments that aimed at improving the operation of their holdings. They found that larger farms were more likely to invest than smaller counterparts in terms of utilized agricultural area. Positive relationship was also found between farm size and investment by Lefebvre *et al.* (2014) and Hennessy and O' Brien (2007).

According to Petrick (2004), who investigated the investment behaviour of credit-rationed farmers in Poland, the value of the investment and farm size associated positively, but excluding the credit effect, large farms seemed to invest less. His results suggested that larger farms obtained larger credit volume thus spend less on non-productive activities.

2.4.1.2. Age and education

When investigating the role farmers' age in investment decision, most studies cite the life cycle effect, whereby "the probability of investment initially grows with age as young farmers grow their businesses but it then eventually declines with age as older farmers prepare for retirement" (Hennessy and O' Brien, 2007, p. 8). However, the role of education of farm manager is a less frequently examined factor.

Olsen and Lund (2009) found significant relationship between investment and years from settlement, namely, farmer was more likely to invest the fewer years he had been farming. They concluded, that younger farmers were more likely to invest than older counterparts, suggesting that younger farmers wish to expand their operation and to increase the income. As reported by Lefebvre *et al.* (2014), farmer's age is a significant factor in investment decision through the life-cycle effect which refers to the future perspective of the farm. Farm exit and succession generally reduce the intention to invest, but the presence of the successor can alleviate the decrease in investment. This result is in line with the findings of LaDue *et al.* (1991), their results are also consistent with the life cycle of farm managers. In addition, Niavis *et al.* (2020) pointed out that the relationship between farmers' age and their investment behaviour was not linear, there seemed to be phases in the life of farmers with different rates of investment. However, the model of Hennessy and O' Brien (2007) did not reveal any significant effect of age on investment decision.

According to the education of the manager, the results of Lefebvre *et al.* (2014) indicated that farmers with higher education were more likely to intend to invest. This result is in line with the finding of Niavis *et al.* (2020), that there was positive and significant relationship between farmers' education and investment decision. In turn, Wieliczko *et al.* (2019) found that education negatively impacted on investment decision, because the non-agricultural work undertaken by higher educated farmers discouraged agricultural investment.

2.4.1.3. Diversification

The role of diversification on investment decision is not a widely researched topic. A few studies have investigated the relationship between income diversification and farm investment, but the impact of production diversification and crop diversification on investment is quite unexplored.

Income diversification: According to Hennessy and O' Brien (2007), there are conflicting theories about the role of off-farm income in investment decision. On the one hand, the presence of off-farm income may release more capital for on-farm investment. On the other hand, farmers with off-farm work operate the farm less profitable and less intensive which reduce the probability of farm investment. However, Lefebvre *et al.* (2014) did not find any significant relationship between off-farm work revenues and intention to invest. In addition, they presented that percentage of professional time dedicated to on-farm work was not differentiate significantly for farmers intending to invest and farmers not intending to invest. Hennessy and O' Brien (2007) showed that low off-farm earnings discouraged investment, but high off-farm earnings had no significant effect on investment.

2.4.1.4. Subsidies

Direct payments and investment support also can impact investment decision. However, the role of direct payment in investment decision may be smaller than that of investment support.

Direct payment may encourage farm investment because it reduces the risk of bankruptcy (Vercammen, 2007). This might increase farmers' willingness to take risky production decision, such as investment (Lefebvre *et al.*, 2014).

Lefebvre *et al.* (2014) reported that both direct payment and investment support encouraged the intention to invest. Firstly, direct payment may facilitate investment by reducing income risk and by relaxing credit constraints in the presence of capital market imperfections. Secondly, investment support encourages investment that otherwise would not have been undertaken (e.g., too high cost, limited access to credit). However, Sckokai and Moro (2009) found that an increase in intervention price could significantly impact on farm investment due to reduced price volatility, while an increase in the Single Farm Payment would have a much smaller impact.

Fertő *et al.* (2012) investigated investment among French, Hungarian and Slovakian farms for the period 2004-2008 for Hungary and Slovenia and for the period 2003-2007 for France. They found that gross farm investment was positively associated with investment subsidies, which implied that investment subsidies could mitigate some capital market imperfection.

2.4.1.5. Economic and financial performance

In connection with economic and financial performance, most studies have showed significant effect of farm income on investment decision, but few research have also focused other indicators, e.g., financial leverage.

According to Niavis *et al.* (2020), disposable income may be an influencing factor of investment. Their model revealed that increasing farm income encouraged investment on capital improvement, suggesting that wealthier farmers seemed to invest more. Hennessy and O' Brien (2007) also presented positive impact of farm income on investment, but they drew attention to the potential endogeneity problem between income and investment. On one hand, investment may be higher because income is higher and there are more sources to invest. On the other hand, income may be higher due to hight investment which increases the productive capacity of the farm.

Regarding to financial leverage, Olsen and Lund (2009) assumed, that the lower the farm debt ratio was, the higher was the ability to obtain loan for a new investment. In turn, their model revealed significantly positive effect of financial leverage on investment decision.

2.4.1.6. Crop insurance take-up

The role of crop insurance take-up in investment decision is quite unexplored, thus further research required to investigate the relationship between investment decision and crop insurance usage.

Karlan *et al.* (2014) investigated the relationship between crop insurance usage and investment decision with a conducted experiments in Ghana in which farmers were offered cash grants, rainfall insurance grants or a combination of the two. The authors found that insurance usage significantly increased agricultural investment, suggesting that the uninsured risk was a constraint on farm investment. In addition, uptake of insurance could lead to riskier production choices among the investigated farms.

2.4.1.7. Other influencing factors

In the literature, several other factors have been also investigated related to investment decision, such as risk attitude, farming type, investment history, market conditions and connection to research. In the following, each factors listed above are illustrated with an example.

Risk attitude: Risk attitude significantly influences investment behaviour; risk-seeking farmers revealed higher willingness to invest compared to risk-averse counterparts (Hermann *et al.*, 2015).

Farming type: Farming type also has an influence on investment. Arable crop farms are more likely to intend to invest compared to livestock farmers, perennial crop farmers and mixed farms (Lefebvre *et al.*, 2014).

Investment history: Investment history has a positive effect on current investment; farmers who invested recently are more likely to intend to invest again (Lefebvre *et al.*, 2014).

Market conditions: Market conditions also affect farms' investment decision. Fertő *et al.* (2012) found that gross farm investment had a positive relationship with real sales growth which suggested that investment decisions depended on market conditions. Their model also revealed positive association between gross investment and cash flow, which implied the absence of soft budget constraints.

Connection to research: Engagement in information gathering activities and participation in research project influence positively the farms' investment decision (Niavis *et al.*, 2020).

3. RESEARCH METHODS IN BRIEF

3.1. 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?

3.2. 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 (Zubor-Nemes *et al.*, 2018, p. 178).

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.

3.3. 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 referred 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).

4. PAPER 1: SPATIAL AND TEMPORAL DEVELOPMENT OF SUBSIDISED CROP INSURANCE IN HUNGARY

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4.1. Abstract

Farmers face a variety of risks, of which the most important is the production risk arising from the unpredictable nature of weather and other uncertainty factors. This paper describes the expansion in space and time of subsidised crop insurance in Hungary, particularly the government-subsidised all-risk insurance scheme. The empirical analysis was based on insurance data and utilised area from the period 2012-2016. Firstly, Moran's *I* index was applied to examine the spatial pattern of insurance use. The index shows a significant neighbourhood effect with respect to location in both the total of all subsidised, and the all-risk schemes. Secondly, using the dynamic spatial autoregressive model, the authors found that the level of insurance take-up is determined by the previous year's level, as well by production structure (i.e., arable v. fruit v. vegetable crops) and farm size. There is no statistically-significant effect of production structure and farm size on the take-up of all-risk insurance. The high level of fruit production in Hungary discourages farmer participation in the subsidised insurance scheme, implying that further refinement of the two-scheme risk management system is necessary.

Keywords: all-risk insurance, Moran's *I*, risk management, SAR model

4.2. Introduction

Farmers face a variety of risks, of which the most important is the production risk arising from the unpredictable nature of weather and other uncertainty factors (Hardaker *et al.*, 2004). The escalating level of risk to crop producers arising from more frequent extreme weather events and climate change increases the need for more tailored risk management tools (Kemény *et al.*, 2012). Among these, crop insurance is one of the most important, and a variety of 'yield insurance' schemes provide cover against all the major climatic hazards, but not against losses caused by plant diseases (Bielza Diaz-Caneja *et al.*, 2009). However, the provision of crop insurance is often not attractive to commercial insurers because of the high level of risk and the high loss ratio. Consequently, crop insurance is expensive, and most producers cannot afford to purchase it. Therefore, subsidies on premiums have an important role in increasing farmers' participation in crop insurance schemes (Kemény *et al.*, 2010). For example, Cortignani and Severini (2012) concluded that the crop revenue insurance scheme in Italy was not profitable for the insurance companies and that a market could be only developed if premiums were subsidised. Similarly, the U.S. government recognises that it has a role in maintaining and developing crop insurance schemes and prefers to support farmers' purchases of insurance ex ante rather providing disaster aid ex post (Bulut, 2017).

The EU also pays attention to risk management in crop production. The risk management toolbox is the part of the current Common Agricultural Policy (CAP, 2014-2020), as described in Regulation (EU) No 1305/2013, incorporates animal and plant insurance (Art.37), mutual funds for animal and plant diseases and environmental incidents (Art.38), and income stabilization tools (Art.39) to manage income volatility (EC, 2017). This toolbox is available under the second pillar. The Member States are allowed to support insurance premium up to 65 per cent in case of insurance products that compensate losses exceeding 30 per cent. This is a favourable change compared to the previous CAP period (2009-2013) when the premium support was available via the direct payment envelopes and the support of premium rates was set at maximum level of 10 percent (Meuwissen *et al.*, 2018).

Private single peril insurance is available in the vast majority of EU Member States (Santeramo and Ramsey, 2017). The largest multi-peril crop insurance programs are in France, Spain and Italy. In Austria index-based insurance is also offered targeting drought risk to some specific crops and grassland (Meuwissen *et al.*, 2018). Subsidised crop insurance is available in Austria, Belgium, Croatia, France, Hungary, Italy, Lithuania, Malta, the Netherlands, Portugal and Spain. Of these, Italy and Spain have the largest programmes, which subsidise yield insurance premium up to 65 per cent, nevertheless the participation is low. Germany is the only country offering multi- peril insurance without subsidies (Santeramo and Ramsey, 2017).

In Hungary, to ensure an adequate level of risk protection for farmers, a new, subsidised, two-scheme system, covering both damage mitigation and crop insurance, was introduced by the government in 2012 (Kemény *et al.*, 2012). This two-scheme system is unique in EU in that farmers may receive compensation from both schemes for the same period of time. Participation in the damage mitigation scheme is compulsory[4] for all farms above a certain size[5]. Compensation is offered only if the overall losses at the farm level exceed 30% of the production value[6]. Under the crop insurance premium support scheme, the financial support cannot exceed 65% of the premium paid. Compensation from subsidised crop insurance is payable when the loss of crop yield exceeds 30% (Kemeny *et al.*, 2014).

Three types of subsidised insurance are available in Hungary and these cover different combinations of crops and natural hazards. The 'A' type (also referred to as 'all-risk') insurance covers all major natural risks – hail, storm, winter frost, spring frost, autumn frost, drought, heavy rain, flood and fire – for major arable and major fruit[7] crops. The 'B' type insurance is available specifically for vegetable crops, minor fruit[8] crops and some major arable crops, and addresses only the major risks: hail, winter frost, autumn frost, storm and fire. The 'C' type insurance covers all relevant crops for any damage not covered by insurance types 'A' and 'B'. The aim of the 'A' type insurance is to cover all relevant natural risk for the major crops. Therefore, the insurance premium is the highest in this case. The 'B' and 'C' types give the choice to the farmers to specify one or more risks covered by the insurance usually at lower fees.

[4] The compensation contribution is HUF 1,000 per hectare for arable crops and HUF 3,000 per hectare for fruit and vegetable crops.
[5] Above 10 hectares for arable crops, above 5 hectares for vegetables and above 1 hectare for fruits.
[6] Between 2012 and 2015 the limit was 30% but in 2016 this limit was reduced to 15%.
[7] Major top fruits (e.g., apple and pear) and grapes.
[8] Minor top fruits and all soft fruits.

In year 2016 the ‘A’ type insurance was used by 3,253 crop producers, ‘B’ type by 8,398 and ‘C’ type by 4,623. Overall, 11,193 different farmers paid for subsidized crop insurance that year. The insurance premium paid by these farmers was HUF 7,877 million. That was a huge increase compared to the 1,896 insurance contracts and HUF 1,467 million insurance fee in 2012.

The participation of farmers in crop insurance schemes is influenced by several factors, one of which is location. Adhikari *et al.* (2010) studied heterogeneity in decision making among US maize producers about the purchase of yield-based or revenue-based crop insurance. They found heterogeneity with clustering effects, i.e., an individual’s participation was influenced by the actions of nearby farmers. This result is in line with Tobler’s First Law of Geography, namely that ‘everything is related to everything else, but near things are more related than distant things’ (Tobler, 1970). Several other factors can affect insurance use. Goodwin (1993) found that among U.S. maize producers both the type of business and farm size have an impact; corporations and larger farms are more likely to purchase insurance. Sherrick *et al.* (2003) and Enjolras and Sentis (2011) also found evidence of a farm size effect among U.S. maize and soybean farmers and French famers. The difference in the cost of insurance premiums between arable, fruit and vegetable crops also has an impact on the extent of insurance take-up. Insurance premiums for fruit crops are expensive compared to arable and vegetable crops, and this reduces the willingness of farmers to buy insurance cover (Keményné Horváth *et al.*, 2017).

The aim of this paper is to investigate the spatio-temporal development of subsidised[9] crop insurance usage in Hungary during the first five years of the current scheme, i.e., between 2012 and 2016, with regard to both the total extent of subsidised insurance and the different insurance types, especially all-risk (‘A’ type) insurance. Hungary is the first post-socialist European Union Member State to implement such a scheme. By studying the factors driving the trends, policy recommendations on how the scheme can be improved can be made. Furthermore, the literature about spatial expansion of

[9] Non-subsidised insurance is also available to farmers in Hungary, but detailed data are not available about it. In any case, the authors were interested solely in the spread and drivers of subsidised insurance, which accounts for a very high share of all crop insurance. In 2016 this proportion was about 70% of total written premiums. Thus, non-subsidised insurance has been excluded from our analysis.

crop insurance is sparse, and this analysis can add to the available pool of knowledge on this topic.

In this paper, two separate hypotheses were tested concerning subsidised crop insurance usage in Hungary:

Hypothesis 1: The intensity of insurance use has a spatial pattern, as farmers' insurance decisions are influenced by the decisions of nearby producers.

Hypothesis 2: Crop insurance level is influenced by production structure, namely a high rate of fruit production has a negative effect, and a high rate of vegetable production has a positive effect on insurance take-up at settlement (LAU 2) level.

The spillover effect was also studied: official Hungarian data suggest that the year- on-year increase in crop insurance level has a positive effect on the take-up of insurance, and a model was used to confirm whether or not the years' contribution is positive.

Although the exposure of the different risks varies by region, the total area of Hungary faces some weather risks. For example, hail and drought risks are high for the whole country. The hypotheses do not consider the insured weather risks, only the fact of insurance use was investigated regardless of the risks covered. The 'A' type insurance is an exception because it covers all major natural hazards. The 'B' and 'C' types insurances covers the risks the farmers choose from the options. Hail insurance is typically purchased under 'B' and 'C' types.

4.3. Materials and methods

The empirical analysis used crop insurance data collected by the Research Institute of Agricultural Economics (AKI) in Budapest, Hungary and utilised area data (according to the location of the farm) from the Integrated Administration and Control System (IACS) for the period 2012-2016. The data were analysed at settlement (LAU 2) level. Moran's *I* index is used to evaluate the spatial pattern of subsidised crop insurance use and the dynamic spatial autoregressive model (SAR) was used to examine the factors influencing crop insurance take-up in terms of type of insurance and percentage of eligible area insured, also taking into account the spatial relationship. Lagged insurance rate, cultivation structure (the area shares of arable, fruit and vegetable crops) and average insurable farm size (i.e., not including areas of forest and grassland) were tested. The data availability limited the analysis. Some other factors may also have influence on insurance-take-up (e.g., income level), but only the data listed above are available for all farms with subsidised insurance. The level of income has probably some impact on insurance use but unfortunately income data are not available at the level investigated. The average farm size is the best available proxy for income level which refers to the amount of SAPS (Single Area Payment Scheme) payments. This subsidy represents a significant part of the income in case of crop producers.

Moran's *I* Index

The Moran's *I* index is widely used to measure the degree of spatial association for the whole data set (Cliff and Ord, 1981; Fischer and Wang, 2011). Moran's *I* uses cross-products to measure value association. Moran's *I* is given by equation (1):

$$(1) \qquad I = \frac{n}{W_o} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2},$$

where n is the number of settlements in the sample, i , j are area units, x_i is the value of the variable of interest for area i, W_{ij} is the weight that expresses the similarity of i's and j's locations, W_o denotes the normalising factor expressed by equation (2).

$$(2) \quad W_o = \sum_{i=1}^{n} \sum_{j \neq i}^{n} W_{ij}.$$

The spatial autocorrelation test is used to examine the spatial arrangement of data values based on Moran's *I* statistic. The null hypothesis is that nearby areas do not affect each other. In contrast, under the alternative hypothesis of spatial autocorrelation, large values are surrounded by other large values (referred to as positive spatial autocorrelation) or small values are surrounded by large values (referred to as negative spatial autocorrelation). Positive spatial autocorrelation implies a spatial clustering of similar values, while negative spatial autocorrelation implies a checkerboard pattern of values. Spatial autocorrelation is considered to be present when the test statistic computed for a particular pattern takes on a large value compared to the expected value under the null hypothesis.

The Moran's *I* index was calculated for each year separately. In this case, the weight matrix used by the Moran's *I* index was calculated based on contiguity edges corners (sometimes referred to as Queens's case contiguity). Polygons that share an edge or a corner is weighted equally, and those that do not share an edge or corner are excluded from the calculation (their weight is zero).

Dynamic spatial autoregressive model

The development of spatial statistics applied to panel data provides a control for spatial and temporal dependencies simultaneously. There are several methods for fitting spatial panel models and these are divided into two categories: generalised method of moment and quasi-maximum likelihood (Baltagi, 1995; Elhorst, 2010). The dynamic spatial autoregressive model was applied (SAR) which is designed for equation (3).

$$\text{(3)} \qquad \mathbf{y}_t = \tau\mathbf{y}_{t-1} + \rho\mathbf{W}\mathbf{y}_t + \mathbf{X}_t\boldsymbol{\beta} + \mu + \boldsymbol{\epsilon}_t$$

where $\mathbf{y}_t$ is the $n \times 1$ vector describing the dependent variable, $\mathbf{X}_t$ is the $n \times k$ matrix of regressors, where n denotes the number of observations and $t = 1 \dots T$ denotes the time periods, $\mathbf{W}$ is the $n \times n$ spatial weight matrix describing the spatial arrangement of the n units, ρ is the scalar spatial autoregressive coefficient with $|\rho| < 1$, $\boldsymbol{\beta}$ is the $k \times 1$ parameter vector of regressors, μ is the individual effect and $\boldsymbol{\epsilon}_t$ is the error term. The STATA xsmle module (Belotti *et al.*, 2017) was used to estimate the parameters; xsmle implements only the fixed-effect variants for the dynamic SAR model using the bias-corrected quasi-maximum likelihood estimation. The $\mathbf{W}$ spatial weight matrix was defined the same way for the Moran's I index: the contiguity edges corners definition was applied so that the results are comparable.

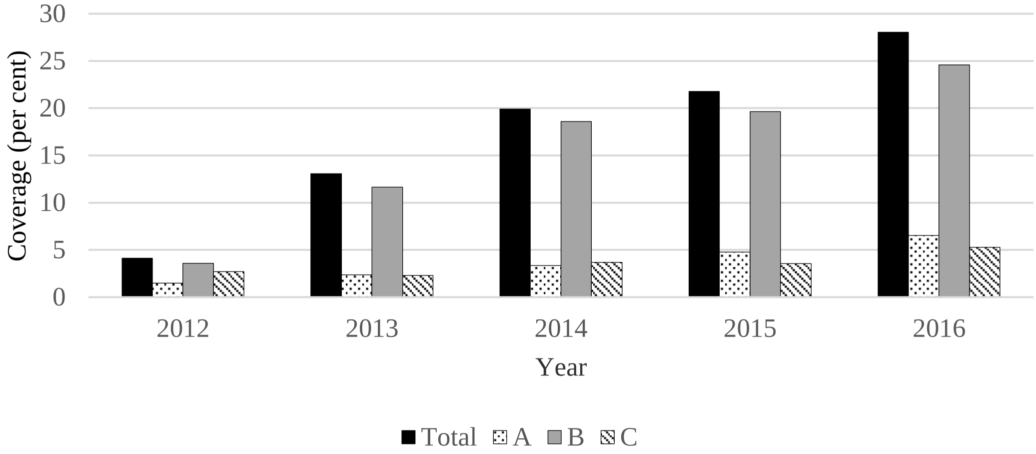
4.4. Results

The total insurable crop area in Hungary, including the 'A', 'B' and 'C' type insurable areas, is about 4 million hectares. Figure 4 shows the area coverage of subsidised insurance as a percentage of the total insurable area by insurance type. The combined[10] coverage of all three types of insurance increased dramatically from 4% in 2012 to 28% in 2016. Vegetable crops achieved the largest increase in insurance level, from 5% to 36%. The level of arable crops insurance went up from 4% to 29%. The smallest

[10] For combined (all types) insurance, the reference area is the total area which can be insured by 'A', 'B' or 'C' type insurances. By contrast, the reference area for 'A' type insurance is only the 'A' insurable area, for 'B' is only the 'B' insurable area and for 'C' is only the 'C' insurable area. For example, oilseed rape can be included in 'A' but not in 'B' type insurance, therefore the oilseed rape area is included in the 'A' and 'C' types and combined insurance levels, and excluded from the 'B' type insurance level.

change in insurance level, from 4% to 7%, was for fruit crops. The level of all-risk ('A' type) insurance increased from 2% to 7% of the total insurable area by 2016; this means that the insured area increased from 50,000 hectares to 210,000 hectares over four years.

Figure 4*: Area coverage by subsidised crop insurance type in Hungary between 2012 and 2016, per cent*



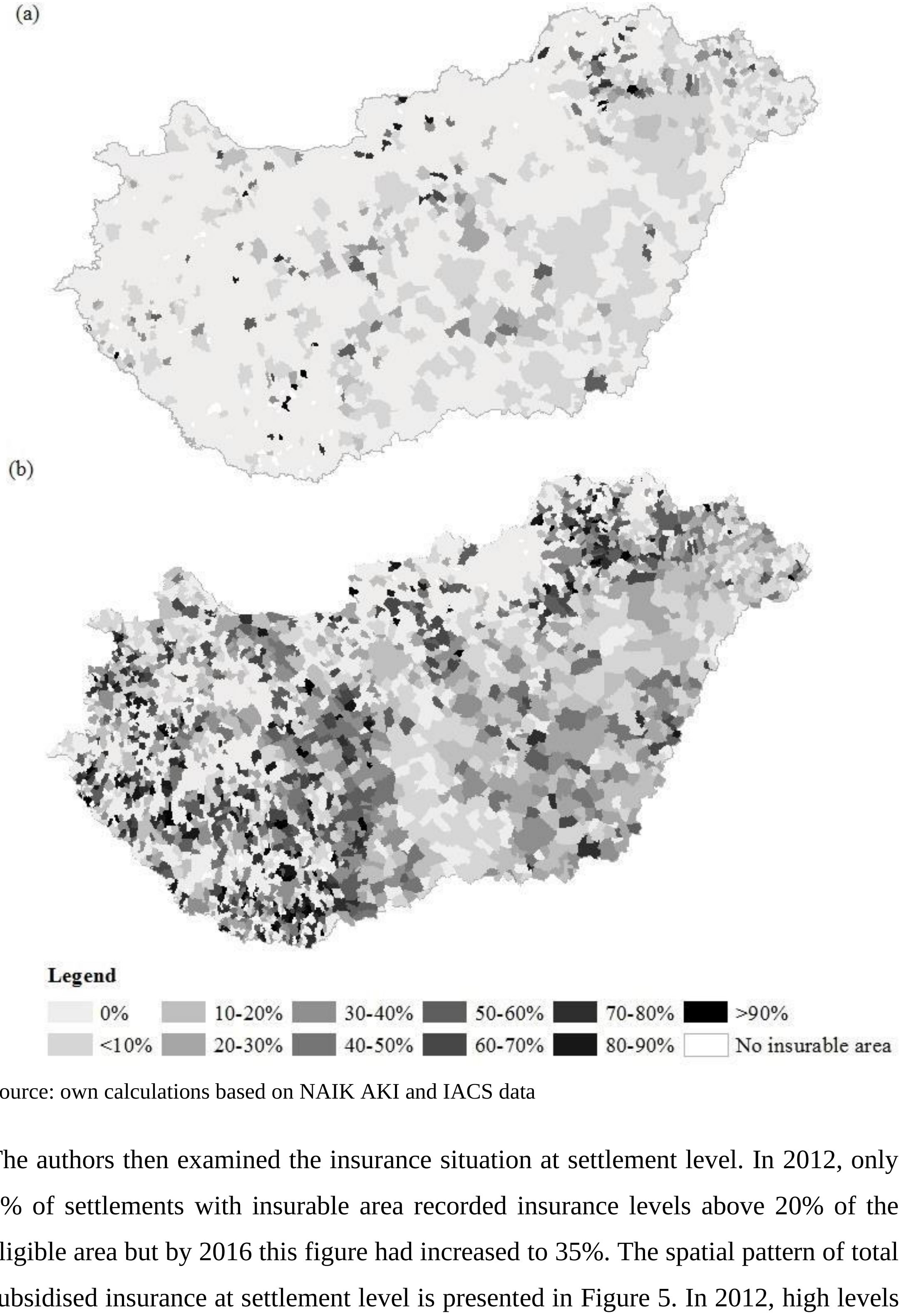
Source: own calculations based on AKI data

Table 1: *Summary of the Moran's I statistics by type of insurance and year for the period 2012-2016*

Year	All types	'A' type	'B' type	'C' type
2012	0.0943 (8.9603)	0.1623 (15.4404)	0.0328 (4.6129)	0.0420 (4.0262)
2013	0.1274 (12.0995)	0.1301 (12.3365)	0.1238 (11.6788)	0.0349 (3.3565)
2014	0.1449 (13.7041)	0.1552 (14.6548)	0.1262 (11.8559)	0.0413 (3.9425)
2015	0.1544 (14.6040)	0.1062 (10.0020)	0.1496 (14.0146)	0.0929 (8.8226)
2016	0.1834 (17.2898)	0.0873 (8.1976)	0.1888 (17.6555)	0.1055 (9.9915)

z-scores are shown in parentheses
Source: own calculations based on AKI and IACS data

Figure 5: *The spatial patterns of subsidised crop insurance levels in Hungary in (a) 2012 and (b) 2016*



Source: own calculations based on NAIK AKI and IACS data

The authors then examined the insurance situation at settlement level. In 2012, only 4% of settlements with insurable area recorded insurance levels above 20% of the eligible area but by 2016 this figure had increased to 35%. The spatial pattern of total subsidised insurance at settlement level is presented in Figure 5. In 2012, high levels of insurance occurred in only a few settlements (Figure 5a) but by 2016 the level of insurance had also increased significantly in some nearby settlements (Figure 5b).

Table 1 shows the Moran's *I* statistics by year for the period 2012-2016. The Moran's *I* indexes are statistically significant at the 1% level and the z-scores are positive, meaning that the null hypothesis can be rejected globally and for each type of insurance for each year during this period. The spatial distribution of similar values in the dataset is more clustered than would be expected if the underlying spatial processes were random. For all types of subsidised insurance taken together, the Moran's *I* values increased year on year, indicating that insurance level in neighbouring settlements converged. Similarly, individual take-up of the 'B' and 'C' type insurances also became more clustered over the period 2012-2016. In contrast, the 'A' type insurance level became less clustered, although the overall take-up of this type of insurance increased.

To investigate the spatial relationship of insurance further, the SAR model was used with lagged insurance use and additional exogenous variables, such as proportions of fruit and vegetable areas, and farm size.

Table 2: *Descriptive statistics of variables included in the dynamic spatial- autoregressive model*

Variable	No. obser- vations	Mean	Std. dev.	Min.	Max.
Share of insured area (%)[1]	15,130	12.15	22.32	0.00	100.00
Share of 'A' type insured area (%)[1]	14,840	2.83	10.74	0.00	100.00
Share of 'B' type insured area (%)[1]	12,505	10.80	21.17	0.00	100.00
Share of 'C' type insured area (%)[1]	15,130	2.48	7.01	0.00	97.66
Share of fruit crop area in total area insured (%)	15,130	6.11	14.49	0.00	100.00
Share of vegetable crop area in total area insured (%)	15,130	1.79	5.10	0.00	100.00
Average insurable farm size (ha)	15,130	32.80	61.87	0.26	1,845.54

Note: [1] as a percentage of total eligible area.
Source: own calculations based on NAIK AKI and IACS data

The descriptive statistics of settlement level variables included in the models are presented in Table 2.

Table 3: *Dynamic spatial-autoregressive model*

Variable	All types	‘A’ type	‘B’ type	‘C’ type
Lagged subsidised insurance level (%)	0.4584***	0.4480***	0.3867***	0.2642***
	(0.0163)	(0.0392)	(0.0170)	(0.0190)
Share of fruit crop area in the total insurable area (%)	-0.1017**	-0.0112	-0.1102***	-0.0195
	(0.0478)	(0.0198)	(0.0407)	(0.0121)
Share of vegetable crop area in the total insurable area (%)	0.0856**	-0.0245	0.2157***	-0.0017
	(0.0411)	(0.0295)	(0.0717)	(0.0130)
Average insurable farm size (ha)	0.0260*	0.0094	-0.0148	0.0033
	(0.0147)	(0.0098)	(0.0192)	(0.0049)
2014	1.7088***	0.3957**	2.1753***	1.1133***
	(0.3107)	(0.1679)	(0.3406)	(0.1158)
2015	1.4774***	1.3222***	1.4513***	0.8467***
	(0.3085)	(0.1906)	(0.3393)	(0.1157)
2016	3.5897***	1.5640***	3.4813***	1.9119***
	(0.3825)	(0.2001)	(0.4178)	(0.1471)
Spatial ρ	0.1269***	0.0764***	0.1146***	0.1191***
	(0.0153)	(0.0165)	(0.0165)	(0.0181)
R2 within	0.1238	0.0326	0.0831	0.0234
R2 between	0.8811	0.8550	0.8197	0.6773
R2 overall	0.5480	0.4147	0.4344	0.2248
N	12,104	11,872	10,004	12,104

Standard errors are shown in parentheses.
* P<0.05, ** P<0.01, *** P<0.001.
Source: own calculations based on NAIK AKI and IACS data

The results of the SAR model are presented for total subsidised insurance and for different insurance type (Table 3).

In the SAR model for all types of subsidised insurance taken together, all the variables are statistically significant. The lagged subsidised insurance level has a significant and positive effect on insurance take-up. The fruit crop area has a significantly negative coefficient, meaning that the average level of insurance cover is lower in settlements with a higher share of fruit production in the total insurable area. The average farm size also has a statistically significant, positive effect on the average level of insurance cover.

The lagged subsidised insurance levels are also positive and statistically significant in the models of the ‘A’, ‘B’ and ‘C’ type insurances. The effect of the shares of fruit and vegetable crop areas in the total insurable area is statistically significant only in the model of the ‘B’ type insurance, and the signs are the same as for the ‘all types’ model. The effect of the average farm size is statistically insignificant for the ‘A’, ‘B’ and ‘C’ models. The years 2014-2016 also have a statistically significant and positive effect on insurance usage compared to 2013.

The spatial ρ indicates positive and significant spatial relationship for the combined case and for each type of insurance separately. This result is consistent with the Moran’s *I* statistics. The ρ coefficient is the lowest for the all-risk (‘A’ type) insurance, which is in line with the decreasing Moran’s *I* index.

The large differences between the within and between R2 statistics show that the results explain rather the cross-section part of the model than the time series part. This can be explained by the relatively stable variables such as share of fruit crops and vegetable crops. For ‘all types’, ‘A’ and ‘B’ insurances, the between R2 statistics are over 0.8, showing that the models can account for a large proportion of variation over space in insurance usage.

4.5. Discussion

The results show that there is a spatial relationship among the insurance decisions of Hungarian crop producers. The rapid increase in the take-up of subsidised insurance between 2012 and 2016 fostered by market growth and the expense of non- subsidised insurance (Kemeny *et al.*, 2014) was not uniform across the country. The biggest increase in the insurance level occurred in western Hungary. Here, the share of fruit crop area in the total insurable area is lower than in other parts of the country, and the average farm size is bigger. In addition to the crop production structure and farm size, farmers’ insurance decisions were also influenced by the behaviour of their neighbours and their use of insurance in the previous year. Thus, the results provide support for hypotheses H1 and H2, namely that, for all types of subsidised insurance taken together, farmers’ insurance decisions are influenced by those of their neighbours and the production structure of the farm. But only H1 is confirmed for each type of insurance separately. Any significant evidence was not found to support H2 for all-risk ('A' type) and 'C' type insurances.

The Moran's *I* statistic confirmed the spatial relationship among the levels of total insurance and each type of insurance; therefore, Tobler's First Law of Geography applies to the spread of subsidised crop insurance in Hungary. But there are different trends by type of insurance. The Moran's *I* statistic increased for total insurance, 'B' and 'C' type insurance, and decreased for 'A' type insurance. The reason for the decreasing Moran's *I* statistic for the latter is that 'A' type insurance levels in the settlements were fairly low across the country in 2012. The increase between 2012 and 2016 was not uniform. By 2016 some settlements had high levels of insurance sporadically resulting lower Moran's *I* statistic. It is anticipated that in the coming years the level of 'A' type insurance will also increase in the nearby settlements. By contrast, the insurance level of the total insurance, 'B' and 'C' type insurance were relatively high for some settlements located sporadically in 2012. The increase of insurance level nearby these settlements causes the increase of Moran's *I* statistic by 2016.

The result, namely the existence of spatial relationship in insurance decision is in line with the findings of Adhikari *et al.* (2010) for U.S. maize producers. They suggested that if a farmer has yield insurance, but sees that many nearby farmers are using revenue insurance, he or she may switch to the more popular option. This theory may also apply to insured versus non-insured farmers. Settlements with high levels of crop insurance may induce more intensive insurance use in nearby settlements. Another reason for the similar behaviour among neighbouring farmers can be that slowly-emerging weather risks such as drought are spatially correlated (Odening and Shen, 2014), meaning that neighbouring farms can face similar weather risks.

Other factors were also analysed that influence the decision to purchase crop insurance. The first of these is the lagged insurance level. The results from the model support the evidence from official data sets that the farmer's experience from the previous year has a positive influence on their decision to participate in the subsidised insurance scheme. This is important because it means that once a farmer that joins the system, they are likely to continue to participate. As with the lagged insurance use, the years' contribution is also positive for total insurance and for each type of insurance.

While the lagged insurance use can be considered as an 'individual' (settlement-level) experience, the years' contribution is the general experience of participation in the subsidised insurance system. The years' contribution in the early stage of the subsidised insurance scheme can be partly explained by farmers switching from non-subsidised to subsidised insurance. But at a later stage of this scheme the years' contribution indicates mostly entry by new users of crop insurance.

According to Goodwin (1993), Sherrick *et al.* (2003) and Enjolras and Sentis (2011), farm size also has a positive impact on overall crop insurance use in the U.S. and France. The authors found similar evidence of an impact of farm size for total insurance. The larger farms can more easily afford to pay for crop insurance. In addition, the insurance companies focus on larger farms for businesses reasons.

The production structure (i.e., arable v. fruit v. vegetable crops) is also a determining factor, but evidence was found for this only for total insurance and 'B' type insurance (Table 3). The reason of insignificance of production structure in case of 'A' type is that the all-risk insurance is not available for most fruit crops and vegetables and the non-insurable areas were not taken into consideration in the analysis. The fruit crop and vegetable producers prefer the 'B' type insurance to 'C' type if it is available for the crop chosen, because the risks covered by 'B' type insurance are sufficient for these producers and the minimal level of risk premium support is at least 40 percent for 'B' type and 30 per cent for 'C' type (the minimum level for 'A' type insurance is 55 per cent). These reasons explain on the one hand the determining role of production structure in case of 'B' type insurance and the insignificance of vegetable and fruit crop level in case of 'C' type insurance.

A high share of fruit production discourages participation in the subsidised insurance system. This can be explained by the typical damage scale. Hail and spring frost can severely damage fruit crops and can cause a high level of financial loss at the farm level, too. In Hungary, high farm-level financial loss entitles farmers to compensation from the damage mitigation scheme. For fruit crops, the farmer's damage mitigation scheme contribution is relatively low compared to arable crops. For small, non-diversified farms with high shares of fruit production, the first scheme is an alternative way to insure. Nevertheless, the damage mitigation scheme compensation does not replace the insurance compensation but complements it.

4.6. Conclusion

The primary purpose of this research was to examine the impacts of spatial relationship and farm structure on the take-up of subsidised crop insurance. Although several studies have previously investigated the factors affecting insurance use, to the best of the authors knowledge, none have examined the spatial relationship of insurance use at settlement level. The empirical results show that settlements with high levels of crop insurance can induce more intensive insurance use in nearby settlements. This finding 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.

There will be an increasing need for subsidised crop insurance because of the effects of climate change and more frequent extreme weather conditions. The Hungarian subsidised two-scheme risk management system is a unique approach that is designed to expand coverage of both the area of production insured and the range of weather risks beyond what can be achieved only with non-subsidised insurance. The evaluation of the system's performance can therefore provide important insights for the further development of insurance products in other EU Member States. From this analysis, the authors conclude that some improvements to the system are possible. In particular, since a high share of fruit production discourages participation in the subsidised insurance system, both the damage mitigation scheme and the insurance scheme for fruit production need further refinement.

This study evaluates the spatial and temporal development of subsidizes crop insurance regardless of the risks covered. Further research is needed to investigate the spread of insurance for the weather risks separately, e.g., hail, drought, spring frost. In this case the regional probability of risk incidence also should be considered.

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5. Paper 2: Farmers' Responses to the Changes in Hungarian Agricultural Insurance System

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5.1. Abstract

Purpose: The aim of this paper is to investigate the role of crop insurance among Hungarian crop farmers and the responses to the introduction of the two-scheme risk management system. Specifically, first it examines the economic and environmental factors affecting the willingness of farmers to contract crop insurance. Second it reveals the relationship between having crop insurance and technical efficiency of crop producing farms.

Design/methodology/approach: Probit models of panel data are applied to explore the factors of insurance decisions. The relationship between efficiency and insurance is investigated with two-stage Data Envelopment Analysis [DEA] model with double bootstrap using panel data for the 2001 to 2014 period.

Findings: The results of Probit model estimations show that the education, the size, the indebtedness of crop producing farms and the new two-scheme risk management system are in positive correlation, while the concentration of farming activity are in negative correlation with the crop insurance contracting. The estimations of two stage DEA model reveal that crop producing farms with an agricultural insurance contract are more efficient than the farmers without using this risk management tool.

Originality/value: Empirical investigation of the influencing factors of agricultural insurance demand in Hungary and the examination of the relationship between insurance and technical efficiency may contribute to the development of Hungarian risk management system.

Keywords: Risk management, Agricultural insurance, Efficiency, Hungarian agriculture, Double bootstrap, DEA

5.2. Introduction

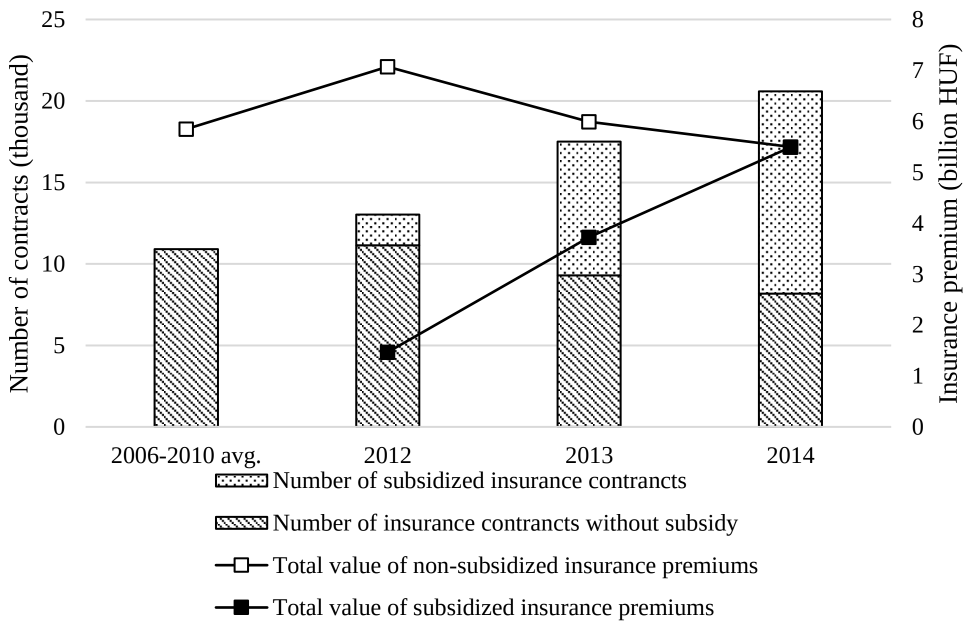
The ecological potential of agricultural production – especially for arable crop production – is favourable in Hungary (IIASA/FAO, 2012). However, the crop production is particularly exposed to adverse natural events, such as floods or drought. Moreover, it is expected to suffer from increased incidents of heat waves and droughts without possibilities for effectively shifting crop cultivation to other parts of the years (Olesen *et al.*, 2011). Increasing climatic risk exposure due to natural hazards such as more fervent extreme weather conditions also increases adaption pressure (Di Falco *et al.*, 2014). Among the possible adaptation measures, technology development and the accompanying efficiency increase is certainly desirable.

As a response to these challenges, providing a more tailored risk management and insurance tools for farmers are of great importance to public policy. In the last few decades, the government has attempted several initiatives in order to foster farmers' self-care related to agricultural risk management (Kemény *et al.*, 2010). The first program between 1996-2004 offered ad-hoc subsidy for certain crop disaster insurance schemes. During these years neither the number of involved farmers, nor the area insured changed in a significant manner. Moreover, the natural hazards involved did not broaden, natural hazards like drought, spring frost were not present in the scheme. The Damage Mitigation System (DMS) substituted the market-based crop insurances from 2007. This still did not bring much change, since it offered only damage compensation and payments covering about 10 to 20% of all losses. The DMS operated on voluntary bases between 2007 and 2008, while between 2009 and 2011 it was compulsory to agricultural organizations and individual businesses. The DMS fund was financed 50-50% by farmers' contribution and state support.

In order to eliminate the low cover rate of the DMS a new two-scheme system was introduced in 2012, providing both disaster damage mitigation and supported crop insurance schemes (Kemény *et al.*, 2012). The first scheme damage mitigation system is compulsory for all farms above 10 hectares in case of crop production, 5 hectares in case of vegetable production and 1 hectare in case of plantations. The second scheme premium support cannot exceed 65% of the premium paid, while three insurance packages are available combining different crops and natural hazards. The ‘A’ package includes the major arable crops with possible cover for hail, draught, flood, winter and spring frost, rain- and thunderstorm and fire or any combinations of these. The ‘B’ package is available for horticulture and addresses hail, winter frost, thunderstorm and fire risks. The ‘C’ package includes all crops for any damage not included in ‘A’ and ‘B’.

The introduction of the two-scheme DMS led to almost double both the total number of contracts and the amount of insurance premium collected (Figure 6). The rapid increase of subsidized insurance is fostered by market growth and at the non-subsidized insurance expenses (Kemeny *et al.*, 2014).

Figure 6: *Insurance premiums and number of contracts between 2006 and 2014*



Source: Authors’ calculation based on data from Association of Hungarian Insurance Companies [MABISZ]

Farming characteristics like risk perception, farm size, education of farm manager, insurance participation in the past, income level, crop mix and input use affect insurance uptake has been a topic of considerable debate (Farrin *et al.*, 2016; Goodwin *et al.*, 2004; Tóth and Nemes, 2014; Wang *et al.*, 2016). According to Brick and Visser (2015, p. 3) “risk-averse individuals are more likely to opt into traditional agriculture (reflected as traditional seeds in the experiment) and are less likely to use modern farming inputs that require financing (high-yield varieties) despite the availability of insurance”. With crop insurance farmers manage weather risks and they are willing to adopt innovative and efficiency enhancing production technologies (Shaik, 2013).

The aim of the paper is to investigate farmers’ responses to the development of Hungarian risk management system, by examination of the economic and environmental factors affecting their willingness to contract insurance policies and of the relationship between use of crop insurance and production performance.

The paper is structured as follow: The next section presents a brief introduction to the literature on the crop insurance demand and on the efficiency and crop insurance. The third section presents the probit model and the two-stage DEA with double bootstrap in the new application. The results of the empirical investigations are discussed in the fourth section. The summary and conclusions are provided in the last section.

5.3. Background

A large body of literature has examined the factors underlying farmer participation in crop insurance programs or demand for insurance with specific goal in mind. For example, the starting point for Nieuwoudt *et al.* (1985) was, that the factors explaining farmer participation in a crop insurance programme depends on (a) the farmer's utility function of income, (b) his current income, (c) his subjective frequency distribution of future income, (d) the change in the frequency distribution of future income generated by the contract and (e) the premium of the contract. Makki and Somwaru (2001) used the Artificial Neural Network model where the insurance products were assumed to be a function of level of risk coverage measured as the probability of revenue or yield falling below the guarantee level, loss frequency and cost of insurance. The role of farm attributes was studied by Mishra and Goodwin (2003) using multinomial logit model to predict changes is used for predicting the adoption of revenue products. Sherrick *et al.* (2003) also studied farmers’ preferences for crop insurance using survey data for corn and soybeans in the Midwest. They used conjoint analysis based on insurance product and farm characteristics. Demand for crop revenue and yield insurance based on the subjective probabilities was carried out by Shaik *et al.* (2008). They elicited subjective probabilities from decision makers under uncertainty regarding their expectation for the future returns. Spatial heterogeneity in insurance participation was first considered by Adhikari *et al.* (2010). They have examined how the demand for particular insurance products varies across space or the heterogeneity in insurance product decisions based on ex ante risk factors.

Determinants of insurance demand can be categorized into groups of variables indicating risk management substitutes, the farmer's risk perception and attitude, farm risk exposure and farm characteristics such as size, economic and financial performance or investment (Baráth *et al.*, 2017). In addition, non-farm income and regional inequalities may influence the insurance demand of rural household (Li *et al.*, 2017).

With increasing diversity of production, the possible weather risks are also growing (Menapace *et al.*, 2012). Therefore, we expect more intense insurance activity if the diversity of produced crops is increasing (concentration rate is decreasing), consequently we expect a negative relation in case of concentration variable. The less diversified the production is the less likely that the farm will use crop insurance. Diversification can be considered an alternative to crop insurance (Calvin, 1992) and on the other hand diversification is also referred as a sign of risk averse attitude, which possibly lead to more insurance use (Enjolras and Sentis, 2011). Therefore, risk averse farms beside diversification also use insurance.

Previous studies (Sherrick *et al.*, 2004) provide evidences that management abilities, behaviour and risk attitude play significant role in taking out insurance. We have also assumed that the better qualified farm managers are contracting more often crop insurance. Although there are mixed arguments on the effect of farm size, we follow Baráth *et al.* (2017) and expect that the use of crop insurance should be higher for larger farms in Hungary. Although Enjolras and Sentis (2008) indicate a significant negative impact of financial performance on insurance demand, since Hungarian farmers evidently facing budget constraints, farm financial performance is expected to have a positive impact on the crop insurance demand (Baráth *et al.*, 2017).

Several empirical studies have investigated the determinants of technical efficiency in case of agricultural producers (Bakucs *et al.*, 2012; Bakucs *et al.*, 2010; Baráth and Fertő, 2015; Bojnec *et al.*, 2014; Bojnec and Latruffe, 2009; Davidova and Latruffe, 2007; Hansson and Öhlmér, 2008; Latruffe *et al.*, 2004; Latruffe *et al.*, 2016), no published papers to the best of authors' knowledge has evaluated the effect of the use of crop insurance on the technical efficiency of crop farming. Depending on the extent to which adverse selection and moral hazard is taking place (Quiggin *et al.*, 1993), the overall impact of crop insurance on a farm's technical efficiency might be positive or negative.

5.4. Method and data

In order to depict the main characteristics of the two-scheme national risk management system descriptive statistics using micro data of the participants are used. Probit model using panel data is used to explore the factors of insurance decisions. Investigations of the effects of agricultural insurance and other environmental factors on technical efficiency are examined using two-stage Data Envelopment Analysis (DEA) method. First, we are estimating technical efficiency scores and in the second stage we are applying multivariable truncated regression analysis with double bootstrap to investigate the influence of agricultural insurance and other environmental variables on technical efficiency. For the probit and two-stage DEA models we make use of the Hungarian FADN data. Data of crop specialized farms for the period of 2001-2014 are used. The Hungarian FADN also includes farm characteristics information (Keszthelyi, 2017). Among others, farm manager characteristics such as age and education, farm structural characteristics such as farm legal form, and most important, data about crop insurance premiums are available. Unfortunately, since 2007 the insurance premium FADN variable also includes the DMS premium. Therefore, after 2007 we had to estimate the insurance premium considering the possible DMS premium specific at the farm level. contribution. The list of variables used and their description is provided in Table 4.

Table 4: *Variables used in the models*

Variable	Description
Age of manager	Age of the farm manager.
Training of manager	Agricultural training of the manager (0: no 1: yes).
UAA	Utilized agricultural area (ha); size indicator.
Concentration	Concentration of crop production. Calculated as the share of two major crops in the arable area.
Insurance	Whether the farm has a crop insurance in a given year (0: no 1: yes).
Lagged insurance	Whether the farm has a crop insurance in a previous year (0: no 1: yes).
Crop insurance use	Total crop insurance premium (1000 HUF/UAA).
Investment rate	Change in fixed assets per UAA.
Indebtedness rate	Liabilities without subordinated liabilities as a share of liabilities.
ROE	Return on Equity (net income returned as a percentage of equity).
Output	Gross production value without subsidies (1000 HUF).
Labour	Annual working unit [AWU] (sum of worked hours/2200).
Capital	Tangible assets (1000 HUF).
Intermediate consumption	Material expenses (1000 HUF).
Technical efficiency	Technical efficiency (TE), CRS efficiency.
Pure technical efficiency	Pure technical efficiency (PTE), VRS efficiency.
Scale efficiency	Scale efficiency (SE), TE/PTE.
2007-2008 period	Dummy: 1 for 2007-2008, 0 otherwise.
2009-2011 period	Dummy: 1 for 2009-2011, 0 otherwise.
2012-2014 period	Dummy: 1 for 2012-2014, 0 otherwise.

Probit model

We made use of pooled probit and panel probit models to reveal the influencing factors of being insured. Based on the review presented in the theoretical framework section we included the following influencing factors: management (age, training), production (utilized agricultural area [UAA], concentration of production), financial status (indebtedness rate, return on equity [ROE]), last year insurance decision, and the effect of the stages of the DMS. Since the random effects model cannot be estimated with lagged dependent variable, lagged insurance variable is only included in the pooled probit model. The descriptive statistics of variables used in the probit model are given in Table 5.

Table 5: *Descriptive statistics of the variables included in probit models*

Variable	Number of observations	Mean	Std. Dev.	Min.	Max.
Insurance	13,764	0.39	0.49	0.00	1.00
Age of manager	13,668	52.32	10.95	19.00	99.00
Training of manager	12,258	0.72	0.45	0.00	1.00
UAA	13,764	232.64	429.29	1.23	5,506.69
Concentration	13,763	0.76	0.17	0.27	1.00
Lagged insurance	11,294	0.38	0.49	0.00	1.00
Indebtedness rate	13,764	0.17	0.21	0.00	6.44
ROE	13,763	0.13	4.36	-260.67	328.60

Source: Authors' calculation based on FADN data

According to Wooldridge (2010) and Wooldridge (2013) we propose the following model:

$$P(y_{it} = 1|\, \mathbf{x}_{it}) = G(\, \mathbf{x}_{it}'\boldsymbol{\beta}),\, i = 1, \dots, N_t\,,\, t = 1, \dots, T \quad (1)$$

where $G(\cdot)$ is a known function taking on values in (0,1) interval, y_{it} is the dependent variable, $\mathbf{x}_{it}$ can contain a variety of factors, including the lagged dependent variable. The y_{it} dichotomous variable is considered in the following form:

$$y_{it} = \begin{cases} 1 & \text{if } y_{it}^* > 0 \\ 0 & \text{if } y_{it}^* \leq 0 \end{cases} \quad (2)$$

where $y_{it}^* = \mathbf{x}_{it}'\boldsymbol{\beta} + u_{it}$. The error term u_{it} independent of $\mathbf{x}_{it}$.

In case of $G(\cdot)$ is the cumulative normal distribution we called (1) pooled probit model. We estimate $\boldsymbol{\beta}$ with maximum likelihood method. Using pooled cross sections raises minor statistical complications. For instance, the population may have different distribution in different time periods. This is accomplished by including time dummy variables. The pooled model can suffer from omitted variable problems. Including the previous year dependent variable can mitigate this problem. An alternative way is using panel data to view the unobserved factors affecting the dependent variable. The unobserved factors can be constant or vary over time.

Based on Baltagi (2005), the random effects [RE] probit model takes into consideration the individual effect denoted by μ_i. The variable μ_i captures all unobserved, time-constant factors affecting y_{it}, thus making the estimation more robust. In this case $u_{it} = \mu_i + \nu_{it}$.

$$P(y_{it} = 1 | \mathbf{x}_{it}, \mu_i) = G(\mathbf{x}'_{it}\boldsymbol{\beta} + \mu_i), i = 1, \dots, N_t, t = 1, \dots, T \quad (3)$$

where $y^*_{it} = \mathbf{x}_{it}{}'\boldsymbol{\beta} + \mu_i + \nu_{it}$ and the distribution of μ_i and ν_{it} is standard normal in case of probit model and μ_i and ν_{it} independent of each other and $\mathbf{x}_{it}$. This assumption of strict exogeneity rules out the lagged dependent variables. The $\boldsymbol{\beta}$ parameters are estimated with maximum likelihood method.

The two-stage DEA with double bootstrap

The two most frequently used efficiency analysis approaches are the Stochastic Frontier Analysis [SFA] which is based on parametric econometric techniques and Data Envelopment Analysis [DEA], which uses nonparametric mathematical programming techniques. Efficiency measurement in DEA is done by construction of frontiers and the measurement of efficiency relative to the constructed frontiers and subject to certain assumptions about the structure of production technology, it envelops the data as tightly as possible (Battese, 1992; Coelli *et al.*, 2005; Thanassoulis *et al.*, 2008).

The advantage of DEA compared to SFA, that it does not require any a priori assumption regarding the production function and the distribution of the error term. However, DEA is sensitive to data/sample quality, particularly sensitive to extreme observations, or outliers. Since the best performer Decision Making Units [DMU] set the frontier, in case there exist any DMU not included in the sample its inclusion to the analysis would shift the frontier upward. In this case DEA would overestimate the efficiency (Latruffe *et al.*, 2012). Simar and Wilson (1998) proposed the use of bootstrap technique which helps to overcome this issue.

Whether one is interested about the input use or the output the optimization can lead to input or output oriented DEA. In the input-oriented models, the goal is to minimize input use for a given input, while in case of output-oriented DEA the output is maximised for a given input mix. In case of constant return to scale [CRS], both approaches provide the same efficiency result, while variable return to scale [VRS] lead to differences. The orientation could be decided based on the DMU [manager of the farm] possibility to control inputs or output (Coelli *et al.*, 2005).

We used output-oriented DEA throughout with CRS and VRS. CRS efficiency of DMUs is taken as total technical efficiency [TTE] while the VRS efficiency of DMU is the pure technical efficiency [PTE]. Scale efficiency [SE] is calculated as their ratio (Coelli *et al.*, 2005). The larger the divergence between VRS and CRS efficiency ratings, the lower the value of scale efficiency and the more adverse the impact of scale size on productivity (Thanassoulis *et al.*, 2008).

Table 6: *Descriptive statistics of the variables used in the two-stage DEA analysis*

Variable	Number of observations	Mean	Std. Dev.	Min.	Max.
Efficiency					
Output	13,331	40,889.34	94,465.81	9.00	1,848,069.00
UAA	13,331	229.09	424.91	1.23	5,506.69
Labour	13,331	3.82	8.88	0.00	215.67
Capital	13,331	46,871.94	75,018.65	2.57	1,468,953.00
Intermediate consumption	13,331	27,103.56	65,827.83	266.97	1,134,799.00
Total technical efficiency (TTE)	13,331	0.52	0.17	0.00	0.98
Pure technical efficiency (PTE)	13,331	0.55	0.18	0.00	0.96
Scale efficiency (SE)	13,331	0.92	0.10	0.06	1.00
Environmental variables					
Age of manager	13,249	52.33	10.97	19.00	99.00
Training of manager	11,967	0.72	0.45	0.00	1.00
UAA	13,331	229.09	424.91	1.23	5,506.69
Crop insurance premium	13,331	0.78	2.16	0.00	99.53
Investment rate	13,331	63.07	136.24	0.00	4,212.65
Indebtedness rate	13,331	0.16	0.20	0.00	3.58

Source: Authors' calculation based on FADN data

In the first stage the efficiency scores are calculated using one output (Gross production value without subsidies) and four inputs (UAA, labour, capital, intermediate consumption). In the second stage almost, the same variables were used to investigate the factors affecting efficiency as in case of the previous insurance decision model: management (age, training), production (UAA, concentration of production), financial status (investment rate). The ROE variable was replaced by investment rate in the second model, because the former variable represents as well an economic performance indicator as the depending variable of the truncated regression.

We also study the effect of being insured on efficiency. The control variable for the premium is the indebtedness rate. We expect to find same sign of these as indebted farms almost always insured. The descriptive statistics of the variables used in this model are given in Table 6.

The method we employed to investigate the relationship between efficiency and crop insurance is a simple panel version of Simar and Wilson [SW] approach with double bootstrap pioneered by Simar and Wilson (2007) and extended by Du *et al.* (2018). This method consists two stages. The first stage is efficiency estimation with DEA, the second stage is truncated regression on covariates with double bootstrap.

Let $\mathbf{x}_i^t \in \mathbb{R}_+^p$ denote a $1 \times p$ vector of inputs, $\mathbf{q}_i^t \in \mathbb{R}_+^q$ denote a $1 \times q$ vector of outputs, $\mathbf{z}_i^t \in \mathbb{R}^r$ denote a $1 \times r$ vector of environmental variables for firm i $(i = 1, \dots, N_t)$ in period $(t = 1, \dots, T)$, $\mathbf{d}^t$ denote dummy variable for period t.

The output-oriented efficiency score for $\left(\mathbf{x}_i^t,\ \mathbf{q}_i^t\right)$ observation under the assumption of constant return to scale (CRS) is estimated with the following linear programming problem in period t:

$$\hat{\theta}_i^t = \max\{\delta > 0 \mid \delta \mathbf{q}_i^t \leq \boldsymbol{Q}^{\boldsymbol{t}} \boldsymbol{\lambda}_t,\ \ \mathbf{x}_i^t \geq \boldsymbol{X}^{\boldsymbol{t}} \boldsymbol{\lambda}^{\boldsymbol{t}},\ \ \boldsymbol{\lambda}^{\boldsymbol{t}} \geq 0\}, \tag{4}$$

where $\boldsymbol{X}^{\boldsymbol{t}} = \left(\mathbf{x}_1^t, \dots, \mathbf{x}_{N_t}^t\right)$, $\boldsymbol{Q}^{\boldsymbol{t}} = \left(\mathbf{q}_1^t, \dots, \mathbf{q}_{N_t}^t\right)$, $\boldsymbol{\lambda}^{\boldsymbol{t}}$ is $N_t \times 1$ vector of intensity variables. The maximization is made over $\boldsymbol{\lambda}^{\boldsymbol{t}}$ and δ.

The case of variable return to scale (VRS) assumption is similar to CRS, the additional condition is $\mathbf{i}'\boldsymbol{\lambda}^{\boldsymbol{t}} = 1$, where $\mathbf{i}$ denotes an $N_t \times 1$ vector of ones. The efficiency scores for the most efficient farms equal to one, greater score means a gap from the DEA-estimated best-practice technology frontier, indicating inefficiency. This is the Farrell (1957) measure of efficiency.

In the second stage DEA efficiency scores are regressed on $\mathbf{z}_i^t$ environmental variables and $\mathbf{d}^t$ year dummies (from 2002 to 2014):

$$\hat{\theta}_i^t = \mathbf{z}_i^t \boldsymbol{\beta} + \mathbf{d}_i^t \boldsymbol{\gamma} + \varepsilon_i^t,\ i = 1, \dots, N_t\,, t = 1, \dots, T, \tag{5}$$

where $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are the corresponding vector of parameters (annual effects on inefficiency). Because of the serial correlation among efficiency scores and the truncated nature of the error term we use the truncated regression with double bootstrap approach pioneered by Simar and Wilson (2007) and extended by Du *et al.* (2018), assuming $\varepsilon_i^t \sim N(0,\ \sigma_\varepsilon^2)$ with left-tail truncation at 1-$\mathbf{z}_i^t\boldsymbol{\beta} - \mathbf{d}_i^t\boldsymbol{\gamma}$ and admitting other statistical regularity conditions outlined in paper of Simar and Wilson (2007, 2011).

The two-stage estimation procedure:

Step 1. Compute $\hat{\theta}_i^t$ based on the original dataset, denoted as $S_{N_t}^t \coloneqq \{(\mathbf{x}_i^t,\ \boldsymbol{q}_i^t): i = 1, \dots, N_t\}$ using (4) separately for each $t = 1, \dots, T$.

Step 2. Organize the estimated efficiency scores from (4) and their factors into panel dataset $S_N \coloneqq \{(\hat{\theta}_i^t, \boldsymbol{z}_i^t\ \boldsymbol{d}^t): i = 1, \dots, N_t, t = 1, \dots, T\}$ with sample size $N = \sum_{t=1}^{T} N_t$. Exclude the observations on the boundary and use maximum likelihood method to obtain an estimate $\widehat{\boldsymbol{\beta}}$ of $\boldsymbol{\beta}$, $\widehat{\boldsymbol{\gamma}}$ of $\boldsymbol{\gamma}$ and $\hat{\sigma}_\varepsilon$of σ_ε in the truncated regression of θ_i^t on $\boldsymbol{z}_i^t$ and $\mathbf{d}^t$.

Step 3. Loop over the next four steps L_1 times to obtain a set of bootstrap estimates $\mathcal{B}_i^t = \{\theta_{i,b}^{t^*}\}_{b=1}^{L_1}$:

Step 3.1. For each $i = 1, \dots, N_t$ and $t = 1, \dots, T$ draw $\hat{\varepsilon}_{i,b}^t$ from $N(0,\ \sigma_\varepsilon^2)$ distribution with left-truncation at 1-$\mathbf{z}_i^t\widehat{\boldsymbol{\beta}} - \mathbf{d}_i^t\widehat{\boldsymbol{\gamma}}$.

Step 3.2. For each $i = 1, \dots, N_t$ and $t = 1, \dots, T$ compute $\theta_{i,b}^{t^*} = \mathbf{z}_i^t\widehat{\boldsymbol{\beta}} + \mathbf{d}_i^t\widehat{\boldsymbol{\gamma}} + \hat{\varepsilon}_{i,b}^t$.

Step 3.3. For all $i = 1, \dots, N_t$ and $t = 1, \dots, T$ set $\mathbf{x}_{i,b}^{t^*} = \mathbf{x}_i^t$, $\mathbf{q}_{i,b}^{t^*} = \mathbf{q}_i^t\ \hat{\theta}_i^t / \theta_{i,b}^{t^*}$, $\mathbf{z}_{i,b}^{t^*} = \mathbf{z}_i^t$.

Step 3.4. Separately for each $t = 1, \dots, T$ compute $\theta_{i,b}^{t^*}$ using (4) but after replacing $\mathbf{x}_i^t$ and $\mathbf{q}_j^t$ with $\mathbf{x}_{j,b}^{t^*}$ and $\mathbf{q}_{i,b}^{t^*}$ for all $j = 1, \dots, N_t$.

Step 4. For all $j = 1, \dots, N_t$ and $t = 1, \dots, T$ compute the bias-corrected estimates $\hat{\hat{\theta}}_i^t$ as $\hat{\hat{\theta}}_i^t = \hat{\theta}_i^t - B(\hat{\theta}_i^t)$, where $B(\hat{\theta}_i^t)$ is the bootstrap estimate of the bias of $\hat{\theta}_i^t$ from Step 3.

Step 5. Organize the bias corrected estimated scores and their factors into panel dataset $S_N := \left\{\left(\hat{\hat{\theta}}_i^t, \boldsymbol{z}_i^t\ \ \mathbf{d}^t\right): i = 1, \dots, N_t, t = 1, \dots, T\right\}$ with sample size $N = \sum_{t=1}^{T} N_t$, and use maximum likelihood method to estimate $\hat{\hat{\boldsymbol{\beta}}}, \hat{\hat{\boldsymbol{\gamma}}}$ and $\hat{\hat{\sigma}}_\varepsilon$ in the truncated regression.

Step 6. Loop over the next three steps L_2 times to obtain a set of bootstrap estimates $\{\hat{\boldsymbol{\beta}}^*, \hat{\boldsymbol{\gamma}}^*, \hat{\sigma}_{\boldsymbol{\varepsilon}}^*\}_{b=1}^{L_2}$:

Step 6.1. For each $i = 1, \dots, N_t$ and $t = 1, \dots, T$ draw $\hat{\hat{\varepsilon}}_{i,b}^t$ from $N(0,\ \hat{\hat{\sigma}}_\varepsilon^2)$ distribution with left-truncation at 1-$\mathbf{z}_i^t\hat{\hat{\boldsymbol{\beta}}} - \mathbf{d}_i^t\hat{\hat{\boldsymbol{\gamma}}}$.

Step 6.2. For each $i = 1, \dots, N_t$ and $t = 1, \dots, T$ compute the double bootstrap analogues of efficiency scores as $\theta_{i,b}^{t^{**}} = \mathbf{z}_i^t\hat{\hat{\boldsymbol{\beta}}} + \mathbf{d}_i^t\hat{\hat{\boldsymbol{\gamma}}} + \hat{\hat{\varepsilon}}_{i,b}^t$.

Step 6.3. Use the method of maximum likelihood to estimate the truncated regression of $\theta_{i,b}^{t^{**}}$ on $\boldsymbol{z}_i^t$ and $\mathbf{d}^t$ resulting estimates $\hat{\hat{\boldsymbol{\beta}}}^*, \hat{\hat{\boldsymbol{\gamma}}}^*$ and $\hat{\hat{\sigma}}_\varepsilon^*$.

Step 7. Use the bootstrap values in $\{\hat{\boldsymbol{\beta}}^*, \hat{\boldsymbol{\gamma}}^*, \hat{\sigma}_{\boldsymbol{\varepsilon}}^*\}_{b=1}^{L_2}$ and the refined estimates $\hat{\hat{\boldsymbol{\beta}}}, \hat{\hat{\boldsymbol{\gamma}}}$, and $\hat{\hat{\sigma}}_\varepsilon$ to construct confidence intervals for $\boldsymbol{\beta}, \boldsymbol{\gamma}$ and σ_ε.

The Simar and Wilson approach uses the Farrell (1957) measure of efficiency which is the reciprocal of Shephard (1970) output distance. The Farrell efficiency is defined on $[1, \infty)$ interval, that can we interpret as inefficiency. To provide a consistent and conventional interpretation of the regression parameters with DEA efficiency scores, we used the Banker and Morey (1986) transformation of environmental variables in Simar and Wilson (2007) approach that applies the Shephard efficiency. Consequently, in the result section the higher efficiency score indicates a more efficient farm.

5.5. Results

The results of the agricultural insurance demand and production efficiency model specifications applied in this paper are presented in the Table 7 and Table 8.

Influencing factors of insurance use

Applying probit models we investigated the determining factors of insurance use of the Hungarian crop farmers, we found positive relationship in case of education of the farmers, crop farm size (UAA) and indebtedness rate, and negative correlation in case of concentration variable for all estimated models (Table 7). The positive relation of farmers' education and insurance contracting is consistent with our previous expectations.

Table 7: *Influencing factors of insurance use*

	Pooled probit parameter		Pooled probit marginal effect		Probit (RE) parameter		Probit (RE) marginal effect	
Age of manager	0.0026	**	0.0010	**	0.0020		0.0007	
	(0.0013)		(0.0005)		(0.0022)		(0.0008)	
Training of manager	0.0883	***	0.0326	***	0.1545	***	0.0532	***
	(0.0320)		(0.0118)		(0.0529)		(0.0182)	
UAA	0.0007	***	0.0002	***	0.0016	***	0.0005	***
	(0.0001)		(0.0000)		(0.0001)		(0.0000)	
Concentration	-0.3840	***	-0.1415	***	-0.4607	***	-0.1587	***
	(0.0874)		(0.0322)		(0.1179)		(0.0407)	
Lagged insurance	1.2546	***	0.4624	***	-		-	
	(0.0290)		(0.0107)					
Indebtedness rate	0.5079	***	0.1872	***	0.6082	***	0.2096	***
	(0.0859)		(0.0316)		(0.1128)		(0.0390)	
ROE	0.0192		0.0071		0.0253		0.0087	
	(0.0221)		(0.0082)		(0.0253)		(0.0087)	
2007-2008 period	0.0181		0.0067		-0.0744		-0.0256	
	(0.0440)		(0.0162)		(0.0471)		(0.0162)	
2009-2011 period	-0.0531		-0.0196		-0.0980	**	-0.0338	**
	(0.0377)		(0.0139)		(0.0416)		(0.0143)	
2012-2014 period	0.1279	***	0.0472	***	0.1119	**	0.0385	**
	(0.0379)		(0.0140)		(0.0439)		(0.0151)	
constant	-0.9739	***			-0.7379	***		
	(0.1023)				(0.1554)			
rho					0.4842			
					(0.0163)			
Log-likelihood					- 6,588,12			
Log pseudolikelihood	-5,291.62							
Number of observations	10,203				12,253			
Number of groups					2,235			

* p<0.1; ** p<0.05; *** p<0.01; for the pooled model the robust standard errors are reported in parenthesis

Source: Authors' calculation based on FADN data

The positive relationship of Hungarian crop farms size and insurance use supports the previous findings that larger farms are more likely take a crop insurance (Sherrick *et al.*, 2004) because crop insurance is relatively expensive, small farms cannot afford (Enjolras and Sentis, 2011). The high positive marginal effect of the indebtedness rate is consistent with anticipated relationship as the insurance use is a prerequisite factor for contracting credits from financial institutions.

The negative sign of the concentration dependent variable is also consistent with our previous expectation discussed above, that the risk averse attitude of Hungarian crop farms is contributing to more insurance use.

The different stages of the DMS development have different effects on the crop insurance demand. The second stage (2009-2011) shows significant and negative correlation to insurance use. The introduction of the two-scheme DMS from 2012 changed the sign and led to positive significant effect on crop insurance use. In the first year of introduction of the new DMS scheme it was common to switch from the non-subsidized contracts to a subsidized one, but from 2013 the size of the insurance market has started to increase.

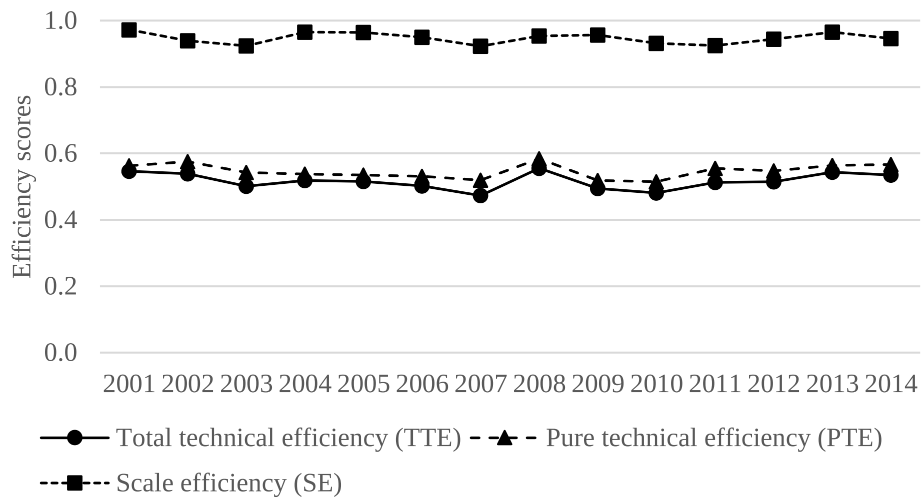
Relationship between efficiency and insurance use

The average technical efficiency and pure technical scores of the Hungarian farms specialized in arable crop production have been stagnating between 0.5 and 0.6 during the analysed period (Figure 7). In the first stage the total technical efficiency and pure technical efficiency scores were calculated using bootstrapping, treating the median of the confidence interval as the true value. However, scale efficiency can be calculated as the ratio of the initial estimation (without bootstrapping). The relatively closed total technical and the pure efficiency scores resulted high scale efficiency scores.

After dividing the sample farms in two sub-samples, insured and non-insured crop producing farms, we found that insured farms have higher average technical efficiency scores than non-insured farms. The normal distribution of technical efficiency scores observed for Hungarian crop producing farms enable us to use T-test for testing the efficiency differences between insured and non-insured farms. We present the 95% confidence interval of the efficiency scores of insured and non-insured farms in

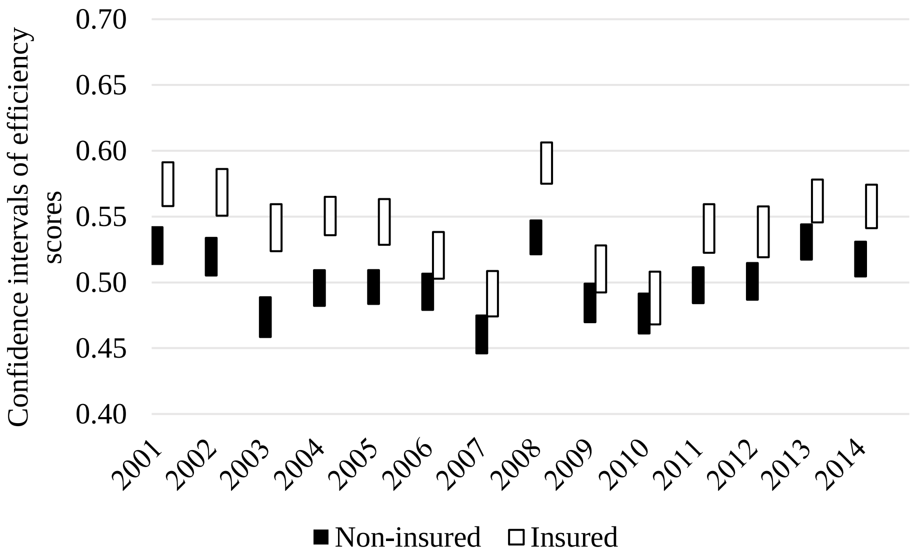
Figure 8. Since the intervals do not overlap – except 2009 and 2010 – the efficiency of the insured and non-insured are different.

Figure 7: *Average efficiency of specialized field crop farms between 2001-2014*



Source: Authors' calculation based on FADN data

Figure 8: *Confidence intervals of technical efficiency scores of insured and non-insured farms between 2001 and 2014*



Source: Authors' calculation based on FADN data

Table 8: *Influencing factors of efficiency*

	Coefficient		Std. Err.	Lower 95% CI	Upper 95% CI
Total technical efficiency					
Age of manager	-0.00093	***	0.00014	-0.00121	-0.00066
Training of manager	0.01664	***	0.00378	0.00955	0.02441
UAA	0.00008	***	0.00001	0.00007	0.00009
Crop insurance premium	0.00270	***	0.00078	0.00121	0.00421
Investment rate	0.00003	**	0.00001	0.00001	0.00005
Indebtedness rate	0.15008	***	0.00989	0.13036	0.16853
2002	-0.02052	**	0.00920	-0.03854	-0.00268
2003	-0.05571	***	0.00903	-0.07385	-0.03854
2004	-0.03577	***	0.00873	-0.05317	-0.01876
2005	-0.03284	***	0.00891	-0.05124	-0.01584
2006	-0.04487	***	0.00931	-0.06317	-0.02634
2007	-0.07547	***	0.00912	-0.09392	-0.05828
2008	0.00791		0.00892	-0.01018	0.02479
2009	-0.04631	***	0.00875	-0.06387	-0.02916
2010	-0.06079	***	0.00861	-0.07829	-0.04419
2011	-0.02894	***	0.00864	-0.04724	-0.01217
2012	-0.02067	**	0.00876	-0.03806	-0.00357
2013	0.01206		0.00858	-0.00522	0.02834
2014	0.00543		0.00899	-0.01236	0.02280
constant	0.53415	***	0.00975	0.51559	0.55281
Pure technical efficiency					
Age of manager	-0.00085	***	0.00015	-0.00113	-0.00056
Training of manager	0.01511	***	0.00362	0.00825	0.02220
UAA	0.00015	***	0.00001	0.00014	0.00017
Crop insurance premium	0.00289	***	0.00079	0.00147	0.00464
Investment rate	0.00004	***	0.00001	0.00002	0.00007
Indebtedness rate	0.13000	***	0.01002	0.10983	0.14946
2002	-0.00962		0.00906	-0.02731	0.00857
2003	-0.03666	***	0.00897	-0.05444	-0.01969
2004	-0.03449	***	0.00881	-0.05246	-0.01710
2005	-0.03353	***	0.00883	-0.04960	-0.01489
2006	-0.04155	***	0.00909	-0.05987	-0.02359
2007	-0.06027	***	0.00890	-0.07728	-0.04163
2008	0.01368		0.00911	-0.00475	0.03058
2009	-0.04664	***	0.00869	-0.06332	-0.02973
2010	-0.05040	***	0.00858	-0.06711	-0.03414
2011	-0.00932		0.00862	-0.02543	0.00751
2012	-0.01359		0.00872	-0.03052	0.00358
2013	0.00772		0.00905	-0.01009	0.02508
2014	0.01308		0.00902	-0.00505	0.02998
constant	0.54276	***	0.01021	0.52183	0.56228

Notes: * $p<0.1$; ** $p<0.05$; *** $p<0.01$
Source: Authors' calculation based on FADN data

The results of the truncated regression estimations obtained in the second stage are presented in Table 8. The positive and significant coefficients estimated in case farm managers' training, farm size (UAA), insurance use, investment rate and indebtedness suggest that a marginal increase in these variables is associated with an increase in farm efficiency. The estimated positive relationship of size and technical efficiency is consistent with previous literature findings (Bakucs *et al.*, 2010; Bojnec *et al.*, 2014; Latruffe *et al.*, 2004). The positive sign of insurance use variable similarly then in the first stage indicate that insured farms are more efficient than non-insured farms. The estimated negative and significant correlation for the age of the manager and year dummy variables imply that younger crop farm managers are more concerned to improve their efficiency and the yearly trend effects are challenging for microeconomic decision makers.

5.6. Conclusions

This paper focuses on the estimation of the farmers' responses to the development of the Hungarian agricultural insurance system by estimations of the relevant factors influencing the farmer responses to agricultural insurances and examining the effects of agricultural insurances on farmers' efficiency.

The probit model estimations indicate that education of farmers, the size of crop farms, the indebtedness of agricultural producers, the new two-scheme risk management system, and the concentration of farming activity have significant influence on the farmer responses to agricultural insurance. All these variables, except concentration are in positive correlation with contracting agricultural insurance policies.

The crop producers with an agricultural insurance contract are more efficient than the farmers without using this risk management tool. The two-stage DEA with double bootstrap results indicate a positive relationship between the considered "environmental" variables and efficiency. This indicates that with insurance use or risk mitigation activity of farmers the efficiency of production is increasing.

Further research is needed to shed light of the path dependency in the insurance demand model and causality effects between efficiency and insurance use. In this paper we did not examine the possible lagged effect of dependent variable in case of panel probit model, which could be overcome in the future using dynamic panel probit model which allow the use of lagged dependent variables (currently partly accounted using pooled models). Finally, future research should examine the causality between efficiency and crop insurance use in order to better signal for future public policy.

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6. Paper 3: The relationship between crop insurance take-up, technical efficiency, and investment in Hungarian farming

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6.1. Abstract

Climate change is putting increasing pressure on agriculture, which might be reduced by paying more attention to risk management, production efficiency and farm investment. This paper describes the interrelationship between crop insurance take-up, technical efficiency and investment in Hungarian farming using a system of simultaneous equations. The empirical analysis is based on farm accountancy data for the period 2001-2019. Results suggest that both technical efficiency and investment have positive and significant effects on insurance take-up. Accordingly, higher technical efficiency and higher investment rate both lead to increased insurance usage. In terms of its with efficiency, insurance has a positive and significant coefficient, but investment does not have a significant influence on technical efficiency. Where investment is concerned, insurance usage has a positive and significant effect but the role of technical efficiency is insignificant. Results suggest that policy interventions that stimulate any of the three factors can potentially have additional positive impacts through spill-over effects on other factors. These effects could be further enhanced if, for instance, interventions focusing primarily on insurance take-up also pay attention to investment by differentiating insurance premium subsidies depending on whether there is an ongoing (or operating) investment that can be linked to weather-related risk management.

Keywords: risk management, farm performance, system of simultaneous equations, Data Envelopment Analysis

JEL classification: G22, L25, Q12

6.2. Introduction

The crop production sector represents about 60 percent of total agricultural output in Hungary (Eurostat, 2020). There are more than 234,000 farms and, based on their main activity, two thirds of them are mainly engaged in crop production (KSH, 2020). The major specialisation is arable crop production and the dominant arable crops are wheat, maize, barley, sunflower and rapeseed. The area of arable land is about 4 million hectares, representing 4 percent of the EU-27 arable land (Eurostat, 2020). Hungarian crop farming is mainly characterised by many small farms and a few very large farms in terms of size in hectares (KSH, 2020).

Hungarian agriculture is heavily exposed to the impact of extreme weather events and climate change due to the high preponderance of crop production. Extreme weather events have become much more common in recent years. For example, in the Carpathian Region in the period 1961-2010, heatwaves became not only more frequent, but also longer, more severe and intense, in particular in summer in the Hungarian Great Plain (Spinoni *et al.*, 2015). In certain parts of Hungary, the number of heatwave days has increased by more than two weeks since 1981 (OMSZ, 2015). Similarly, the frequency of heatwaves has increased across much of Europe (IPCC, 2014).

Changes in precipitation patterns are also observable in Hungary. Annual precipitation has decreased by 5.6 percent between 1901 and 2014, and the reduced precipitation falls in a more intensive pattern which decreases its potential utilisation and increases the frequency of extreme rainfall events. The annual number of rainy days has decreased by 15 days since 1901 (OMSZ, 2015). The increasing number of heatwave days and decreasing number of rainy days raise the likelihood of longer drought periods.

Drought and hail are the most frequent types of crop damage in Hungary and can pose even greater risks to agricultural production in the future. Thus, strategies for adapting to increased weather and climatic risk and for mitigating the potential financial implications are becoming increasingly important. To help alleviate the financial risk related to increased weather and climatic risk, a damage mitigation system (DMS) has been provided by the Hungarian government since 2007 (Kemény *et al.*, 2010).

Assessment of the possible impacts of extreme weather events is an important part of farmers' risk management strategies. Farmers can use several methods to deal with increased weather risk. Firstly, crop insurance can play an important role in mitigating the financial impacts of climate change (Di Falco *et al.*, 2014). Secondly, improving technical efficiency to make more efficient use of natural resources can contribute to adaptation to climate change. Improving technical efficiency is important because of the limited availability of natural resources, such as water and land. Thirdly, investment in agricultural production can also contribute to dealing with the challenges posed by climate change. According to Collier *et al.* (2009), farmers' risk assessments can identify adaptation strategies which can be managed through investments, such as irrigation and modified cropping systems.

Although all three factors can mitigate climate related impacts on crop production, to the author's knowledge, the interrelationships between crop insurance take-up, technical efficiency and farm investment have not been studied to date. Baráth *et al.* (2017) investigated the relationship between crop insurance demand and economic performance measured by farm profit margin and total factor productivity. However, no study to date has, to the author's knowledge, evaluated the effect of technical efficiency on insurance demand. Furthermore, the effects of insurance usage and technical efficiency on farm investment also have not been examined to date.

The main objective of this paper is therefore to investigate the interrelationships between crop insurance usage, technical efficiency and investments in Hungary over a period of nearly twenty years (between 2001 and 2019). By studying the determining factors of farmers' behaviour, policy recommendations on how the crop insurance market can be improved can be made. In addition, such interrelationships may mean that policy interventions also lead to increased technical efficiency and encourage investment.

The paper is structured as follows. The next section presents a literature review, followed by a description of the methodology and data. The results are then presented, followed by the exploration of the new insights gained from the analysis. Finally, these insights are used to formulate some policy recommendations and draw some general conclusions.

In order to examine these interrelationships properly, other drivers of farmers' behaviour towards these three factors also need to be considered. Therefore, an overview of the determining factors follows.

6.3. Literature review

Crop insurance take-up

Several studies show that larger farms are more likely to insure their crops (Baráth *et al.*, 2017; Enjolras and Sentis, 2011; Sherrick *et al.*, 2004). According to Sherrick *et al.* (2004) and Finger and Lehmann (2012), insurance users tend to be older, more experienced and better educated. Crop diversification has an impact on insurance demand, although there are mixed arguments concerning the effect of diversification (non-concentration). On the one hand, Di Falco *et al.* (2014) and Goodwin (1993) found that crop diversification could be a substitute for crop insurance. On the other hand, Mishra *et al.* (2004) suggested that a risk-averse farmer who diversifying his/her production also took out insurance to reduce risk.

The intensity of direct input use (seeds, fertilisers, pesticides, etc.) is a proxy for production intensity, which also may affect insurance usage. Serra *et al.* (2003) found that the application of chemical inputs reduced the expected return from crop insurance, consequently the farmer is less likely to take out crop insurance. This is in line with the result of Smith and Goodwin (1996) showing that producers who purchase crop insurance use fewer agrochemicals. In contrast, Möhring *et al.* (2020) found a positive relationship between crop insurance and pesticide use in European agriculture.

Finger and Lehmann (2012) and Goodwin and Smith (2013) found evidence of the effect of subsidies on insurance use. While there are targeted incentives to adopt crop insurance such as insurance premium support, direct payments may also influence insurance usage. Finger and Lehmann (2012) found that direct payments reduce farmers' insurance take-up. They pointed out that this relationship between premium support and direct payments highlighted contradictory influences of agricultural policy measures. Therefore, this current study examines the effect of total amount of subsidy (except investment subsidy), taking also account other financial support.

Among other determining factors, intuitively, insurance history can be a good proxy of willingness to pay for insurance and the average of the previous three years of insurance usage can be used as the measure of willingness to adopt crop insurance. Lefebvre *et al.* (2014) found that the farmers intending to invest are more likely to have positive attitudes towards innovation and to follow good farm management practices, such as having agricultural insurance. Baráth *et al.* (2017) provided empirical evidence that economic performance, measured by farm profit margin (PM) and total factor productivity (TFP), has a positive impact on farm insurance demand.

Technical efficiency

Latruffe *et al.* (2004) and Bojnec and Fertő (2013) showed that larger farms are more technically efficient than the smaller ones. Dessale (2019) and Nowak *et al.* (2016) found that the age of farm managers had a positive effect on technical efficiency, which they said could be explained by older farmers possessing greater farming experience. According to Dessale (2019), technical efficiency is positively correlated with education, because more educated farmers have the ability to use information from various sources more effectively and are able to apply new farming technologies that would increase outputs.

In terms of production diversification, a more specialised (concentrated) farm may be more efficient as there is no competition for land between activities and farmers can focus their management efforts (Bojnec and Latruffe, 2009). However, Lazíková *et al.* (2019) found that production diversity positively affected technical efficiency.

Subsidies can increase technical efficiency if they provide the necessary financial means to keep technologies up to date or to invest in efficiency improvement (Zhu and Lansink, 2010). On the other hand, subsidies can serve to reduce farmers' effort and consequently reduce their technical efficiency (Bojnec and Latruffe, 2009). Bojnec and Latruffe (2009) and Zhu and Lansink (2010) also found that total subsidies had a negative impact on technical efficiency. According to Pawłowski *et al.* (2021) investments are a basic way to increase efficiency. However, they emphasised that not every investment leads to increased efficiency, owing to the phenomenon of overinvestment.

Investment

The extent of investment is influenced by several factors. Investment history affects the subsequent investments, namely, farmers who invested recently are more likely to intend to invest again (Lefebvre *et al.*, 2014). Larger farms are also more likely to invest (Lefebvre *et al.*, 2014; Niavis *et al.*, 2020). Farmers' characteristics, such as age and education, can also have an impact on investment decisions. The results of Niavis *et al.* (2020) suggested that the relationship between farmers' age and their investment behaviour was not linear, instead one may observe phases in the life of farmer with different rates of investment. According to Wieliczko *et al.* (2019), education can have a negative impact on investment due to the non-agricultural work undertaken by these farmers which discourages agricultural investment. Fertő *et al.* (2017) identified a positive association between investment and investment subsidies. Direct payments also contributed to increasing investment activity in agriculture, although this represents income support and not investment support (Fogarasi *et al.*, 2014).

6.4. Methods and data

The empirical analysis uses micro data of Hungarian farms available from the national farm accountancy data network (FADN) collected by the Research Institute of Agricultural Economics (AKI) in Budapest. The FADN observes the assets-, financial- and income-based situations of a representative sample according to three categories: region, economic size and type of farming. The sample consists of nearly 2000 agricultural holdings from year to year (Keszthelyi and Kis Csatári, 2020). Data from about 1000 crop specialised farms for the period 2001-2019 are used in this study. To investigate the relationship between insurance demand, technical efficiency and farm investment, it is firstly necessary to determine the technical efficiency scores. The efficiency scores are estimated using Data Envelopment Analysis (DEA). Secondly, a system of simultaneous equations is applied to examine the relationship between insurance take-up, technical efficiency and farm investment, also considering other factors, such as farm size, concentration, production intensity, subsidies and information on farmers' characteristics.

The empirical analysis takes account of the three distinct phases of the Hungarian DMS. Initially, the DMS offered only very low compensation for losses (Kemény *et* *al.*, 2010). To help increase the compensation capacity of the DMS, a two-scheme risk management system was introduced in 2012. The first scheme is damage mitigation, in which participation is compulsory for all farms above a certain size in hectares (Péter *et al.*, 2020). The second scheme consists of crop insurance premium support for three types of insurance (‘A’, ‘B’, ‘C’), in which participation is voluntary. Under this scheme, the premium support cannot exceed 65 percent[11] of the premium paid. Between 2012 and 2015 there was no lower limit for premium support, this was introduced only in 2016 (‘A’ type – 41.25 percent, ‘B’ and ‘C’ type – 30 percent). The various types of subsidised insurance cover different combinations of crops and natural hazards (currently specified in the legislation). The ‘A’ type (also referred as ‘all-risk’) insurance covers all the most important weather risks for the major arable and fruit crops. The ‘B’ type insurance addresses the major vegetable crops, minor fruit crops and some major arable crops, and covers only certain major risks. The ’C’ type insurance is available for all relevant crops for any damage not covered by insurance types ‘A’ and ‘B’ (Péter *et al.*, 2020). Since 2012, farmers have had the option to cover weather risk by taking up subsidised or traditional (non-subsidised) crop insurance.

Estimation of efficiency scores

The two principal methods used for efficiency analysis are Stochastic Frontier Analysis (SFA) which uses parametric econometric techniques and DEA which is based on nonparametric mathematical programming techniques to construct a frontier over the data. Efficiency measures are calculated relative to this frontier (Coelli *et al.*, 2005). The main advantage of using DEA over SFA for efficiency measurement is that it does not require any assumption about the functional form and about the distribution of the error terms (Charnes *et al.*, 1994). However, the DEA method is data sensitive. The frontier is highly subject to the errors in the data because this method uses only the extreme observation to identify the ‘best-practice frontier’ (Timmer, 1971).

The statistical estimators of the frontier are obtained from finite sample, consequently, the related measures of efficiency are sensitive to the sampling variations of the obtained frontier (Simar and Wilson, 1998). Simar and Wilson (1998) provided a

[11] In 2020 the limit of financial support was raised to 70 percent.

general methodology of bootstrapping to analyse the sensitivity of nonparametric efficiency scores to sampling variations.

The present study employs output oriented constant returns to scale DEA model with bootstrap method to estimate the technical efficiency scores. The estimation of efficiency scores is based on one output (gross production value without subsidies) and four inputs (land, labour, capital, intermediate consumption).

System of simultaneous equations

To investigate the relationship between insurance use, technical efficiency and investment, a system of simultaneous equations is used. The model is defined by the following equations (Amemiya, 1979; Maddala, 1983):

$$\mathbf{y}_1^* = \gamma_{11}\mathbf{y}_2 + \gamma_{12}\mathbf{y}_3 + \mathbf{X}_1\boldsymbol{\beta}_1 + \mathbf{u}_1 \tag{1}$$

$$\mathbf{y}_2 = \gamma_{21}\mathbf{y}_1^* + \gamma_{22}\mathbf{y}_3 + \mathbf{X}_2\boldsymbol{\beta}_2 + \mathbf{u}_2 \tag{2}$$

$$\mathbf{y}_3 = \gamma_{31}\mathbf{y}_1^* + \gamma_{32}\mathbf{y}_2 + \mathbf{X}_3\boldsymbol{\beta}_3 + \mathbf{u}_3 \tag{3}$$

where $\mathbf{y}_1^*, \mathbf{y}_2, \mathbf{y}_3$ are $N \times 1$ vectors, $\gamma_{11}, \gamma_{12}, \gamma_{21}, \gamma_{22}, \gamma_{31}, \gamma_{32}$ are scalars, $\mathbf{X}_1$ is $N \times M_1$ matrix, $\mathbf{X}_2$ is $N \times M_2$ matrix, $\mathbf{X}_3$ is $N \times M_3$ matrix, $\boldsymbol{\beta}_1$ is $M_1 \times 1$ vector, $\boldsymbol{\beta}_2$ is $M_2 \times 1$ vector, $\boldsymbol{\beta}_3$ is $M_3 \times 1$ vector and $\mathbf{u}_1, \mathbf{u}_2, \mathbf{u}_3$ are $N \times 1$ error terms. The number of farms is indicated by N. The number of exogenous variables in the corresponding equations is denoted by M_1, M_2 and M_3.

Equation (1) refers to crop insurance demand model. The dependent variable $\mathbf{y}_1^*$ indicates the farmer's decision whether to take out crop insurance or not and is observed as a binary variable so that $\mathbf{y}_1 = \mathbf{y}_1^*$ if $\mathbf{y}_1^* > 0$, otherwise $\mathbf{y}_1 = 0$. Equation (2) describes the efficiency model, where the dependent variable $\mathbf{y}_2$ indicates the technical efficiency scores which are estimated with the DEA method, as a result, these are bounded above by 1 and below by 0. Equation (3) corresponds to the investment model. The dependent variable $\mathbf{y}_3$ denotes the amount of net investment and is observed.

The model can be estimated equation-by-equation with the two-stage approach proposed by Amemiya (1979) and Maddala (1983). In the first stage the following reduced-form model is estimated.

$$\mathbf{y}_1^* = \mathbf{X}\boldsymbol{\Pi}_1 + \mathbf{v}_1 \tag{4}$$

$$\mathbf{y}_2 = \mathbf{X}\boldsymbol{\Pi}_2 + \mathbf{v}_2 \tag{5}$$

$$\mathbf{y}_3 = \mathbf{X}\boldsymbol{\Pi}_3 + \mathbf{v}_3 \tag{6}$$

where $\mathbf{X}$ is $N \times M$ vector consisting all exogenous regressors from all equations, $\boldsymbol{\Pi}_1$, $\boldsymbol{\Pi}_2$, $\boldsymbol{\Pi}_3$ are the $M \times 1$ coefficients, and $\mathbf{v}_1$, $\mathbf{v}_2$, $\mathbf{v}_3$ are the $N \times 1$ error terms of the reduced model. The number of distinct exogenous vectors is denoted by M.

Table 9: *Description of variables used in the empirical analysis*

Variable	Description
Age of manager	Age of the farm manager
Training of manager	Agricultural training of the manager (0: no, 1: yes)
Utilised Agricultural Area	Size indicator, utilised agricultural area (ha)
Insurance	Whether the farm has crop insurance in a given year (0: no, 1: yes)
Insurance history	The average insurance use of the last three years. Proxy variable for willingness to take out crop insurance.
Investment	Net investment per 1 hectare of land (HUF 1,000/ha)
Investment history	The average net investment of the last three years (HUF 1,000/ha). Proxy variable for willingness to invest.
Output	Gross production value without subsidies (HUF 1,000)
Labour	Annual working unit (AWU) (sum of worked hours/2,200)
Capital	Tangible assets (HUF 1,000)
Intermediate consumption	Material expenses (HUF 1,000)
Technical efficiency	Technical efficiency (TE), CRS efficiency
Concentration	Concentration of crop production calculated as the share of two major crops in the arable area
Intensity	Cost of seeds, fertilisers and pesticides and other direct material costs (HUF 1,000/ha)
Investment subsidies	Investment subsidies (HUF 1,000/ha)
Subsidies	Total amount of subsidies excluding investment subsidies (HUF 1,000/ha)
2007-2011 period	Dummy: 1 for 2007-2011, 0 otherwise
2012-2015 period	Dummy: 1 for 2012-2015, 0 otherwise
2016-2019 period	Dummy: 1 for 2016-2019, 0 otherwise

Source: own compilation

The coefficients of Equation (4) with the binary dependent variable are estimated with the probit model. The dependent variable of Equation (5) is technical efficiency estimated using the DEA method. When regressing that variable, it is to be considered that the efficiency scores are serially correlated and the error terms are derived from a truncated distribution (Simar and Wilson, 2007). To deal with this issue, the empirical analysis follows Simar and Wilson (2007) and uses truncated regression with double bootstrap to estimate Equation (5). Equation (6) with continuous dependent variable can be estimated using ordinary least squares (OLS). The first stage predicted values are $\hat{\mathbf{y}}_1 = \mathbf{X}\widehat{\boldsymbol{\Pi}}_1$, $\hat{\mathbf{y}}_2 = \mathbf{X}\widehat{\boldsymbol{\Pi}}_2$ and $\hat{\mathbf{y}}_3 = \mathbf{X}\widehat{\boldsymbol{\Pi}}_3$.

In the second stage these fitted values are used as instruments for the endogenous regressors to estimate Equation (1), Equation (2) and Equation (3) following Newey's two step procedure (Newey, 1987). The first step generates residuals from a linear probability regression of the endogenous variables on regressors and instruments. The second step fits the probit, Simar-Wilson and linear regression models on regressors including the first step residuals (Cameron and Trivedi, 2009). The *z* statistics for the coefficients of first step residuals provides the basis of the Durbin-Wu-Hausman test for endogeneity. If some of the coefficients are significantly different from 0, then the second step estimator needs to be adjusted by using the bootstrap method following Cameron and Trivedi (2009).

The list of variables used in the empirical analysis and their description is provided in Table 9. Monetary indicators have been deflated to the year 2001 using price indices provided by Hungarian Central Statistical Office. The related descriptive statistics are presented in Table 10.

Table 10: *Descriptive statistics of the variables*

Variable	Mean	Std. dev.	Min.	Max.
Age of manager	55.84	11.15	20.00	99.00
Training of manager	0.69	0.46	0.00	1.00
Utilised Agricultural Area	227.41	390.14	3.38	5,256.00
Insurance	0.42	0.49	0.00	1.00
Investment	7.79	55.07	-545.23	1488.51
Insurance history	0.40	0.40	0.00	1.00
Investment history	9.07	38.33	-255.75	697.31
Output	42,482.16	87,703.48	102.29	1,776,742.00
Labour	3.63	7.69	0.01	139.24
Capital	56,178.20	78,428.38	2.57	1,265,346.00
Intermediate consumption	27,066.55	60,489.82	304.95	818,440.20
Technical efficiency	0.52	0.17	0.02	0.96
Concentration	0.74	0.17	0.27	1.00
Intensity	42.95	23.96	0.00	547.68
Investment subsidies	1.63	11.07	0.00	343.97
Subsidies	48.34	24.93	0.00	920.75

N=11,362
Source: author's calculations based on FADN data

6.5. Results

The results of the system of simultaneous equations employed in the study are presented in Tables 11, 12 and 13. The endogeneity test based on the significance of first step residuals indicates that technical efficiency and investment are endogenous for insurance take-up, and insurance is endogenous for technical efficiency. Therefore, the second step estimator is adjusted by using the bootstrap method as required.

Results of the insurance take-up model

In addition to technical efficiency and investment, insurance history was found to have a positive and significant effect on insurance take-up (Table 11). The farmer's age positively influences insurance usage, but the contribution of education is not significant. The coefficient of farm size is insignificant. Concentration and intensity significantly decrease insurance take-up.

Table 11: Estimated parameters of the insurance take-up model

	Coefficient		Std. Err.	z	P>|z|	Lower 95% CI	Upper 95% CI
Insurance							
Technical efficiency	4.6762	***	0.6929	6.7500	0.0000	3.3180	6.0343
Investment	0.0031	***	0.0011	2.8800	0.0040	0.0010	0.0052
Insurance history	1.8345	***	0.0433	42.4100	0.0000	1.7497	1.9192
Age of manager	0.0045	***	0.0016	2.9000	0.0040	0.0015	0.0076
Training of manager	0.0156		0.0346	0.4500	0.6530	-0.0522	0.0833
Utilised Agr. Area	0.0001		0.0001	0.6400	0.5200	-0.0001	0.0002
Concentration	-0.8332	***	0.1002	-8.3200	0.0000	-1.0295	-0.6368
Intensity	-0.0087	***	0.0016	-5.4600	0.0000	-0.0118	-0.0055
Subsidies	0.0067	***	0.0012	5.6100	0.0000	0.0043	0.0090
2007-2011 period	0.0199		0.0541	0.3700	0.7120	-0.0861	0.1260
2012-2015 period	0.1022	*	0.0576	1.7700	0.0760	-0.0107	0.2151
2016-2019 period	0.1643	***	0.0580	2.8300	0.0050	0.0506	0.2779
Technical eff. residual	-4.5291	***	0.7004	-6.4700	0.0000	-5.9019	-3.1563
Investment residual	-0.0024	**	0.0011	-2.1800	0.0290	-0.0046	-0.0002
Constant	-3.1069	***	0.3538	-8.7800	0.0000	-3.8004	-2.4135

Notes: *p<0.1; **p<0.05; ***p<0.01
Source: author's calculations based on FADN data

The total amount of subsidies (excluding investment subsidies) affects insurance demand positively. This variable also consists of the premium support which is targeted to increase crop insurance usage. The period 2007-2011 does not have a significant effect on insurance use but in the periods 2012-2015 and 2016-2019 insurance take-up increased significantly. The most recent period has the highest impact.

Results of the technical efficiency model

Insurance usage has a positive and significant effect on technical efficiency (Table 12). However, investment is statistically insignificant for the efficiency model. The age of the farmer negatively influences technical efficiency, but the contribution of education is positive and significant. Farm size also impacts technical efficiency positively. Both concentration and intensity have a positive and significant influence on technical efficiency. By contrast, subsidies significantly decrease efficiency.

Table 12: *Estimated parameters of the technical efficiency model*

	Coefficient		Std. Err.	z	P>|z|	Lower 95% CI	Upper 95% CI
Technical efficiency							
Insurance	0.0318	***	0.0061	5.2400	0.0000	0.0199	0.0437
Investment	0.0000		0.0001	0.3600	0.7160	-0.0001	0.0002
Age of manager	-0.0009	***	0.0001	-6.1800	0.0000	-0.0011	-0.0006
Training of manager	0.0132	***	0.0033	4.0100	0.0000	0.0067	0.0196
Utilised Agr. Area	0.0001	***	0.0000	20.6300	0.0000	0.0001	0.0001
Concentration	0.0249	**	0.0106	2.3600	0.0180	0.0043	0.0456
Intensity	0.0024	***	0.0001	22.1200	0.0000	0.0021	0.0026
Subsidies	-0.0009	***	0.0001	-8.9700	0.0000	-0.0011	-0.0007
Insurance residual	-0.0259	***	0.0073	-3.5500	0.0000	-0.0402	-0.0116
Investment residual	0.0000		0.0001	0.2700	0.7830	-0.0002	0.0002
Constant	0.4488	***	0.0130	34.4000	0.0000	0.4232	0.4744

Notes: *p<0.1; **p<0.05; ***p<0.01

Source: author's calculations based on FADN data

Results of the investment model

Insurance take-up has a positive and significant impact on investment (Table 13). However, technical efficiency does not influence investment significantly. Investment history also has a positive and significant effect on investment. The impact of the farmer's age and education are insignificant. The role of farm size is insignificant in the case of investment decision. Concentration influences investment negatively and significantly, but production intensity has no significant effect on investment. Total subsidies (excluding investment subsidies) and investment subsidies also have a positive sign, both are statistically significant, but the impact of investment subsidies is higher.

Table 13: *Estimated parameters of the investment model*

	Coefficient		Std. Err.	z	P>|z|	Lower 95% CI	Upper 95% CI
Investment							
Insurance	3.8928	*	2.0774	1.8700	0.0610	-0.1792	7.9648
Technical efficiency	35.5510		21.7268	1.6400	0.1020	-7.0374	78.1393
Investment history	0.0853	***	0.0130	6.5400	0.0000	0.0597	0.1109
Age of manager	0.0002		0.0481	0.0000	0.9960	-0.0941	0.0945
Training of manager	0.6342		1.1045	0.5700	0.5660	-1.5307	2.7992
Utilised Agr. Area	-0.0031		0.0023	-1.3700	0.1710	-0.0077	0.0014
Concentration	-15.8671	***	3.2624	-4.8600	0.0000	-22.2619	-9.4723
Intensity	-0.0800		0.0488	-1.6400	0.1010	-0.1757	0.0157
Investment subsidies	1.5280	***	0.0445	34.3100	0.0000	1.4407	1.6153
Subsidies	0.0455	*	0.0265	1.7200	0.0860	-0.0064	0.0975
Technical eff. residual	-0.4926		2.4273	-0.2000	0.8390	-5.2505	4.2653
Investment residual	-29.2752		21.9509	-1.3300	0.1820	-72.3028	13.7524
Constant	-2.2911		10.6342	-0.2200	0.8290	-23.1361	18.5538

Notes: *p<0.1; **p<0.05; ***p<0.01
Source: author's calculations based on FADN data

6.6. Discussion

This study examined the interrelationship between crop insurance take-up, technical efficiency and investment among Hungarian FADN crop specialised farms. All three factors can all play a role in improving these farms' resilience to the impacts of extreme weather events and climate change and the empirical results show that each of them is influenced by several drivers.

Insurance take-up

Insurance take-up is influenced by insurance history, age of manager, concentration, intensity and subsidies but not by training of manager and the farm size. The positive effect of manager's age on insurance take-up, as also shown by Sherrick *et al.* (2004) and Finger and Lehmann (2012), suggests that older farmers are more risk averse. Concentration influences insurance take-up negatively, which is in line with the findings of Mishra *et al.* (2004). This result suggests that a farmer with a diversified crop production structure may also take out crop insurance to further reduce weather risk. The negative role of intensity is in line with findings of Smith and Goodwin (1996) and Serra *et al.* (2003) and confirms that intensification can substitute for insurance usage. Subsidy influences positively crop insurance demand, as also shown by Baráth *et al.* (2017), who argued that subsidies may increase demand for crop insurance by relaxing farm budget constraints. In addition, total subsidy includes insurance premium support, which specifically encourages crop insurance growth.

Differences in research methodology may explain why, unlike Enjolras and Sentis (2011), Sherrick *et al.* (2004) and Zubor-Nemes *et al.* (2018), no significant effect of farm size on insurance demand was detected. The first study applied logistic regression, the second used multinomial logit model and the third applied probit models. The present study investigated the reciprocal effects and the relationship between the three dependent variables may eliminate the direct impact of farm size on insurance demand. Similarly, Baráth *et al.* (2017) applied a system of simultaneous equations and found that the effect of farm size is not significant for TFP specification, only for the PM specification.

The absence of any significant impact of education, in contrast to the finding of Sherrick *et al.* (2004) and Finger and Lehmann (2012), may also be caused by differences in research methodology. The effect of education on insurance demand can be eliminated by using a system of simultaneous equations.

Technical efficiency

Technical efficiency is determined by age of manager, training of manager, farm size, concentration, intensity and subsidies. Farm size positively affects technical efficiency, in line with the findings of Bojnec and Fertő (2013) and Latruffe *et al.* (2004). More educated farmers are more efficient, as shown by Dessale (2019). This implies that these farmers are willing to apply new technology to increase technical efficiency. Concentration positively affects technical efficiency, as shown by Bojnec and Latruffe (2009), suggesting that farmers who can focus their management effort are more efficient than farmers with more diversified cropping structures.

Intensity also increases technical efficiency. Bene *et al.* (2019) modelled the effects of climate change on the yield of winter wheat and maize for the period 2020-2100 and showed that, in the case of maize, the application of the correct amount of nitrogen can reduce yield loss caused by climate change. The negative role of subsidies, as also shown by Bojnec and Latruffe (2009) and Zhu and Lansink (2010) suggests that subsidies can reduce farmers' effort and therefore decrease technical efficiency.

The negative impact of farmers' age on technical efficiency, in contrast to the findings of Nowak *et al.* (2016) and Dessale (2019), suggests that younger Hungarian farmers may adapt much more easily to new technologies, such as digital technologies, than their older counterparts.

Investment

Investment is affected by investment history, investment subsidies and concentration but not by age of manager, training of manager, farm size or intensity. The positive role of investment history is in line with the findings of Lefebvre *et al.* (2014) and confirms that investment history is a good proxy for willingness to invest. Investment subsidies and total subsidies (excluding investment subsidies) also increase investment, as shown by Fertő *et al.* (2017) and Fogarasi *et al.* (2014). It may be that credit market imperfections and the resulting liquidity constraints have an impact on investment decisions of farmers (Bakucs *et al.*, 2009). According to Fogarasi *et al.* (2014), credit market imperfections are slightly compensated by investment support with facilitating the financing of agricultural activity. In addition, they argue that direct payments can also increase investment activity. Concentration has a negative effect on investment. One reason could be that growing fewer types of crops might require less equipment with lower maintenance costs.

The absence of any significant impact of farmer age and education on investment, in contrast to the findings of Niavis *et al.* (2020), suggests that younger and older farmers invest similarly in Hungary. Similarly, the finding that agricultural education does not have a significant effect on investment among Hungarian farmers is not consistent with the findings of Wieliczko *et al.* (2019) in Poland. The current research investigates only the impact of agricultural training and could be extended to include non-agricultural education to get a deeper understanding of the impact of education.

Differences in research methodology may also explain why, unlike Lefebvre *et al.* (2014) and Niavis *et al.* (2020), this study detected no effect of farm size on investment. The former treated the investment variable as a dummy variable and the latter investigated the number of investments. The present study used net investment per hectare and it follows that investments of equal value appear to be smaller for larger farms, which may obscure differences by size.

One reason why intensity has no significant effect on investment may be that the quantitative changes of fertiliser or pesticide use do not influence significantly the equipment needed if the farmers already use these chemicals. In future work it would be useful to investigate the partial effect of the changes on each input separately to see that the aggregation of these inputs is the causes the insignificant result.

Interrelationships between the three factors

Crop insurance usage impacts positively on technical efficiency. Crop insurance provides a safety net; consequently, the producer also receives income in the case of natural damage. This safety might also contribute to developing the technology and improving technical efficiency. Another explanation might be that crop insurance has a premium cost which can pressure the farmer to improve technical efficiency in order to generate additional income to compensate.

As regards the positive and significant impact of technical efficiency on insurance usage, Baráth *et al.* (2017) obtained similar results when investigating the effect of economic performance (measured by farm profit margin and TFP) on insurance demand. This result suggests that managers of farms with higher technical efficiency also consider carefully other aspects of production. They are more likely to subscribe to crop insurance to control risk than managers of farms with lower technical efficiency.

Insurance take-up affects investment positively. The reason may be that the safety net provided by the insurance provides an opportunity for further development.

Investment also encourages insurance demand. Lefebvre *et al.* (2014) similarly found a positive relationship between farmers intentions to invest and other good farm management practices, such as having agricultural insurance. However, some producers use credit to finance investment and insurance subscription is a precondition of contracting credits from financial institutions.

Although investments are a basic way to increase efficiency (Pawłowski *et al.*, 2021), the present study, which investigates the simultaneous effects of insurance take-up, technical efficiency and investment does not reveal any significant interaction between technical efficiency and investment. It may be concluded that since investment has a long-term effect, the current year’s investment improves the technical efficiency only in the following years.

Similarly, the effect of technical efficiency on investment is not significant. This implies that the less efficient and more efficient farms equally willing to invest, especially with appropriate financial support.

6.7. Conclusions and recommendations

Climate change and extreme weather events are putting increasing pressure on agriculture in Hungary as elsewhere. The empirical results of this study show that encouraging insurance take-up by Hungarian crop specialised farms has a positive effect both on their technical efficiency and investment. Simultaneously, development of technical efficiency and investment increase insurance usage.

The model also reveals that significant differences in the insurance demand of farms have already occurred over time. With the introduction of two-scheme risk management system in 2012, insurance usage increased significantly. In 2016, the establishment of lower limit of premium support was even more stimulating. Since Hungarian crop insurance policy has evidently become more effective following revision on several occasions, there may be scope for its further development. Future policy interventions concerning insurance usage may, by taking account of the drivers of farmers' behaviour, potentially have additional positive impacts through spill-over effects on technical efficiency and investments.

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

In view of the different effects of managers' age on insurance take-up and technical efficiency, it may be that the usage of crop insurance should be more forcefully targeted at older farmers. This approach might have a 'knock on' effect on technical efficiency and serve to make farms managed by older farmers more resilient to weather-related impacts.

Since insurance history significantly increases insurance take-up, the insurance companies might focus on farmers who have not purchased crop insurance recently to expand the range of insured. Similarly, since investment history is closely related to current investment, policy concerning investment initiatives might be more forcefully targeted at the farmers who have not invested recently.

Subsidies have a significant role for all three variables. But it seems that in the context of crop insurance, technical efficiency and investment, the targeted financial support is more effective than total subsidies including direct payments. Total subsidies decrease technical efficiency. In contrast, targeted subsidies, i.e., premium support, encourage crop insurance demand and investment subsidies stimulate investment significantly. This finding can help decision makers to further develop agricultural support schemes, for example through the refinement of direct support schemes.

Further research is needed to investigate the dynamic relationship between insurance take-up, technical efficiency and farm investment. This study does not examine the possible lagged effect of dependent variable, only average historical values are taken into account as proxy variables to willingness to insure and willingness to invest. A deeper insight into the causality effects between these variables may be achieved by applying a dynamic panel model.

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7. RESULTS AND CONCLUSIONS IN BRIEF

7.1. Summary of the results regarding to Paper 1

The first paper investigated the spatial pattern of subsidised crop insurance demand for the period 2012-2016. The combined coverage of all three types of insurance increased from 4 percent to 28 percent during the period examined. Vegetable crops achieved the largest increase in crop insurance level, from 5 percent to 36 percent, followed by arable crops (from 4 percent to 29 percent). The increase of insurance take-up was moderate for fruit crops (from 4 percent to 7 percent).

The number of settlements with insurance levels above 20 percent increased from 4 percent in 2012 to 35 percent in 2016. The results showed a significant spatial relationship between settlements regarding to crop insurance purchase. In 2012, high level of insurance evaluated in only a few settlements, but the level of insurance has increased significantly in some nearby settlements by 2016. According to the different types of insurance, the values of the Moran's *I* index indicated that the 'B' and 'C' type insurance became more clustered during the period examined. However, the 'A' type insurance became less clustered by 2016, although the overall take-up of this type of insurance increased.

Considering all types of insurance together, the results of the SAR model revealed that the lagged subsidised insurance level, the share of vegetable crop area in the total insurable area and the average farm size positively influenced the crop insurance take-up for the period 2012-2016. However, the share of fruit crop area in the total insurable area discouraged the crop insurance demand. Regarding to the different types of insurance, the lagged subsidised insurance encouraged insurance take-up for the 'A', 'B' and 'C' type insurances. The crop structure had significant impact only for the 'B' type insurance, and the effects are similar as for the 'all-types' model. The average farm size was insignificant for the 'A', 'B' and 'C' type insurances. The positive spatial relationship was confirmed by the SAR model for all the three types of insurance both separately and together.

7.2. Summary of the results regarding to Paper 2

The second paper identified the influencing factors of farm level insurance decision and the impact of contracting crop insurance on technical efficiency among Hungarian arable farms based on FADN data for the period 2001-2014.

The influencing factors of crop insurance decision was investigated by applying pooled probit model and random effects probit model. Both of the models suggested that managers' training, farm size and indebtedness rate had a positive effect on crop insurance demand in the period examined. In turn, concentration decreased crop insurance take-up. The pooled probit model included lagged insurance variable and this model revealed that lagged crop insurance encouraged current crop insurance use. ROE was insignificant for both models studied. The introduction of the two-scheme risk management system in 2012 contributed to the expansion of crop insurance demand among Hungarian farmers.

The effect of crop insurance and other environmental factors on technical efficiency was evaluated by using two-stage Data Envelopment Analysis (DEA) method with double bootstrap. The results showed that managers' training, farm size, crop insurance take-up, investment rate (measured by change in fixed assets) and indebtedness rate positively influenced both farms' total technical efficiency and pure technical efficiency. However, the age of farmer had a negative effect on the technical efficiency variables.

7.3. Summary of the results regarding to Paper 3

To explore the interrelationship between insurance demand, technical efficiency and farm investment (measured by net investment) system of simultaneous equations was applied. The analysis was based on FADN data for the period 2001-2019. The model revealed that crop insurance demand was affected positively by technical efficiency, investment, insurance history, farmer's age and total subsidies (excluding investment subsidies) which includes premium support. In turn, intensity and concentration decreased insurance take-up, the latter finding is in line with the result of Paper 1. In contrast to the results of Paper 2, the training of manager and farms size had not significant effect on insurance take-up. This can be explained by the differences in the research methodology, the significant effect of education and farm size can be eliminated by using a system of simultaneous equations. Crop insurance contracting significantly increased for both period 2012-2015 and 2016-2019, indicating the positive effect of the Hungarian Agricultural Risk Management System.

Technical efficiency was influenced positively by insurance usage, education of farmer, farm size, concentration and intensity in the period examined. However, age of farmer and subsidies discouraged technical efficiency. Insignificant effect was revealed for investment on technical efficiency.

Investment was increased significantly by crop insurance take-up, investment history, investment subsidies and total subsidies (excluding investment subsidies) between 2001 and 2019. In turn, concentration decreased investment. The impact of technical efficiency, farm size, farmer's age, farmer's education and intensity were insignificant on investment.

7.4. Concluding remarks regarding to the three papers

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

The high share of fruit production discourages participation in the subsidised insurance system, which indicates that both damage mitigation scheme and premium subsidised crop insurance scheme need further refinement concerning fruit production.

Results suggest that policy interventions that stimulate any of crop insurance take-up, technical efficiency and farm investment, could potentially have additional positive impacts through spill-over effects on other factors. Since crop insurance take-up has a positive and significant impact on investment, policy interventions focusing on insurance use might also pay attention to investment, 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 managers' age has different impact on insurance usage and on technical efficiency. Consequently, the usage of crop insurance should be more forcefully targeted at older farmers which might have a ‘knock on’ effect on technical efficiency and serve to make farms managed by older farmers more resilient to weather-related impacts.

Since insurance history encourages insurance take-up, the insurance companies might focus on farmers who have not purchased crop insurance recently to expand the range of insured. Similarly, since investment history increases current investment, policy concerning investment initiatives might be more forcefully targeted at the farmers who have not invested recently.

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 decrease technical efficiency. In contrast, targeted subsidies, i.e., premium support, encourage crop insurance demand and investment subsidies stimulate investment significantly. This finding can help decision makers to further develop agricultural support schemes, for example, through the refinement of direct support schemes.

8. SUMMARY

8.1. 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 14.

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 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 that 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 spill-over effects on other factors, consequently, these farms' resilience to the impact of extreme weather events and climate change might be further improved.

Table 14: *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

8.2. 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.

8.3. 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.

8.4. 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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10. APPENDIX: RELEVANT PUBLICATIONS OF THE AUTHOR

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