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Revisiting the diversification and insurance relationship: Differences between on– and off-farm strategies

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A B S T R A C T

Crop insurance is an important instrument for farmers to cope with climate risks. Yet, also, diversification plays a crucial role. The use of crop insurance and diversification is interrelated. For example, an increasing support and uptake of insurance solutions may discourage farmers to take diversification measures on the farm, given that they now have an insurance dealing with risks. This may have unintended consequences, such as biodiversity decline.

We examine the relationships between seven different kinds of income diversification and the uptake of crop insurance. Theoretically, both substitutive and complementary relationships are possible. The reason is that, depending on their preferences and constraints, farmers choose income bundles that optimally balance profits and risks. Here we provide the first systematic empirical examination of this issue. Our analysis is based on our own survey data from 1176 Swiss fruit growers. We consider on– and off-farm diversification strategies, namely inter-varietal diversity, agro-tourism, processing and direct marketing of products, creation of financial reserves for bad times, forestry work, off-farm investment, off-farm income and their association with insurance uptake. In line with our theoretical reasoning, we do indeed find both substitutive and complementary relationships. In general, on-farm diversification is associated with positive insurance demand, whereas off-farm diversification has a negative association.

1. Introduction

A salient characteristic of agriculture is the intrinsic risk involved. For example, the exposure to climatic risks and climatic extreme events can create losses in yield quantity (Lesk et al., 2016) and quality (Dalhaus et al., 2020) and thus increase the volatility of incomes. Climate change increases the relevance of these risks (e.g. Lunt et al., 2016, Mase et al., 2017; Trnka et al., 2014; Webber et al., 2018). Two common policy responses are subsidized insurance (e.g. in the United States) (Coble and Barnett, 2012) and support for farm diversification (e.g. in Europe) (Meraner et al., 2015). Farmers have a number of risk management strategies at hand, including weather risk management strategies, that can improve the resilience of farms (Vroege and Finger, 2020). These risk management strategies can include crop insurance and diversification decisions, which reduce weather risks.

Hail insurance is the dominant insurance type in Swiss and other central European crop production, therefore understanding its interrelation with other risk management strategies is crucial to understand how farmers make climate risk management decisions and subsequently to develop targeted policies. For example, the uptake of an insurance may discourage farmers to take diversification

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measures on the farm, given that they now have an insurance dealing with risks. If a farmer has an insurance, her/his responses to moral hazard may possibly include a switch to more risky crops (Yu and Sumner 2018) and inputs (Roll 2019) and adjustments in capital structure and investment (de Mey et al., 2016). This effect of crop insurance on the level of diversification is relevant for a wide body of stakeholders. For example, it may affect what and how farmers produce, which has consequences for food supply as well as environmental outcomes such as pesticide use and biodiversity (e.g. Müller et al., 2017, Möhring et al., 2020). The current findings on the interrelationship of crop insurance and diversification are ambiguous.

In this paper, we revisit this relationship by reviewing risk management instruments, including on-farm and off-farm diversification activities and their association with crop (hail) insurance uptake. We argue that the relationship between crop insurance and diversification might vary depending on the type of diversification activity in question. Crop insurance and diversification might be negatively or positively correlated, depending on the type of diversification we are dealing with. Based on data from Swiss fruit growers, we examine whether seven different diversification activities and crop insurance uptake are negatively or positively correlated at the general farm management level. Crop insurances are market-based risk management instruments that provide payouts in case of a given loss event (e.g. due to hail). Diversification is an on-farm risk management instrument. It involves on-farm diversification such as crop species diversity and off-farm measures such as the re-allocation of the farm's production resources to non-farming activities. In this paper, we consider a wide set of diversification measures, namely: i) inter-varietal diversity, ii) agro-tourism, iii) processing and direct marketing of the produce on the farm, iv) creation of financial reserves for bad times, v) forestry work, vi) off-farm investment and vii) share of off-farm income. These diversifications activities are contributing to climate risk management. More specifically, the inter-varietal diversity is a strategy used by farmers to reduce possible impacts of extreme weather. In addition, with off-farm diversification, such as forestry or off-farm work, growers reduce the exposure of their overall income and liquidity to climate risks.

The Swiss case is particularly interesting because, while in many countries, agricultural insurances are subsidized (Moschini and Hennessy 2001, Bardají et al., 2016), Switzerland has (currently) no subsidies on crop insurance premiums allowing for an unbiased analysis of crop insurance use (Finger and Lehmann 2012).

Former contributions on crop insurance – diversification interrelationships include Mishra and Goodwin (2003), Chang and Mishra (2012) and Velandia et al. (2009), who find that in the United States, income diversification and crop insurance are negatively correlated. Similar patterns are found by El Benni et al. (2012) and Wuepper et al. (2018) in Switzerland and Ethiopia, respectively. This negative correlation was not only found for income diversification but also for on–farm diversification, such as the number of crops which are cultivated (Blank and McDonald 1996, Smith and Goodwin 1996, Di Falco and Chavas 2009, O'Donoghue et al., 2009, Enjolras and Sentis 2011, Di Falco et al., 2014). However, other studies find opposite results. For example, studies undertaken by Mishra et al. (2004), Enjolras et al. (2012), Lefebvre et al. (2014) and Goodwin (1993) regard diversification and crop insurance as positively associated. In summary, there have been ambiguous findings on the relationship between diversification and crop insurance uptake.

One main gap in current literature is the lack of a systematic analysis of different kinds of on– and off-farm diversification measures and crop insurance. Today's literature on crop insurance uptake does not distinguish between different types of diversification activities. Studies differ in how they measure and define diversification. Indeed, generally speaking, only one type of diversification activity is considered, whereas farmers have a large portfolio of diversification measures to choose from especially in high value fruit production. For instance, current literature neglects diversification involving different varieties of fruits which is an important risk management strategy adopted by fruit growers. Inter-varietal diversity is especially relevant in fruit production, where mixing early maturing and late maturing varieties is a commonly used climate risk management practice (Haigh et al., 2015). This varietal diversity also generates several ecosystem services (e.g. with respect to pest and disease pressure and pollination (e.g. Hajjar et al., 2008)). Therefore, this diversity and its interaction with crop insurance uptake is of interest for policy-makers. Moreover, insights into the association of crop insurance uptake and on-farm and off-farm diversification strategies provide additional information on possible options for tailoring policies and crop insurance offers.

To fill this gap, we investigate how the relationships between a diversification and crop insurance use differs among different diversification strategies. For this, we collected survey data from 1176 farmers in Switzerland on a large portfolio of risk management strategies that have to the best of our knowledge not been considered so far jointly. Our dataset includes detailed information on seven different types of diversification activities undertaken by farmers, including on-farm diversification strategies such as the use of different fruit varieties but also off-farm diversification strategies not related to the production on the farm, such as forestry activities or off-farm labor. We use regression analysis to estimate the relationship between on-farm and off-farm diversification activities and crop insurance uptake. To avoid biased inference we use the approaches by Imbens (2003) and Oster (2019) to avoid omitted variable bias.

Our main finding is that the relationship between diversification and crop insurance is heterogeneous across different kinds of diversification. On-farm diversification measures tend to be positively correlated to crop insurance uptake, whereas off-farm diversification tends to be negatively correlated. This finding needs to be considered in agricultural policy making, when incentivizing either insurance or diversification to avoid undesired side effects.

2. Theoretical background

Farmers' risk management strategies aim to reduce agricultural risk. They identify the type of risk, potential risk-reducing management strategies and the welfare effects of risk (Chavas and Shi 2015). We assume that risk averse farmers maximize their utility with respect to risk management strategies, including: i) on-farm diversification strategies, i.e. inter-varietal diversification, processing/direct marketing, agro-tourism and creation of financial reserves, ii) off-farm diversification activities, i.e. off-farm investments, forestry work, share of off-farm income and iii) crop insurance uptake.

Crop insurance and diversification are often expected to reduce the anticipated household profits. A higher level of risk management activities often implies extra costs, for example, direct monetary expenditure (e.g. for an insurance premium) or opportunity costs (e.g. forgone efficiency gains from specialization) (e.g. McNamara and Weiss 2005). There might be notable exceptions in the presence of complementarity benefits, which provide incentives to diversify (Chavas and Di Falco 2012). In our case study, for instance, by producing a diversity of fruits and varieties thereof, producers may be able to supply markets continuously and exploit full market potential. Thus, on-farm strategies, off-farm strategies and insurance uptake may or may not decrease expected farm profits.

Climate risk management strategies such as diversification of varieties, on-farm strategies, off-farm strategies and insurance uptake are expected to have risk reducing effects. Assuming that, on average, farmers are risk averse (see e.g. Iyer et al., 2020) farmers are better off with higher levels of expected profit but worse off in higher levels of risk exposure. Farmers face trade-offs as risk management strategies are expected to reduce the variance of their profits but also induce additional costs that might erode their profits.

The optimal allocation of insurance and diversification activities depends on their effects on expected profits and on the variance of profit, farmers' risk preferences, and effects on risk exposure (Barrett et al., 2001). Moreover, this optimization problem is subject to several constraints at the household level, i.e. time constraints (for on– and off-farm work), budget constraints (restricting possible consumption, expenditure and investment) and technology constraints (e.g. limiting the use of specific production technologies) (e.g. Hennessy and Rehman 2008, Fernandez-Cornejo et al., 2005). In addition, choices taken by farmers on risk management strategies are also expected to depend on farm and household characteristics (McNamara and Weiss 2005, Hansson et al., 2013, Weltin et al., 2017), and more specifically also on farmers' risk aversion (Meraner and Finger 2019). Moreover, policies such as decoupled payments may induce farmers to take riskier production decisions on the farm (as highlighted by Hennessy 1998), since farm income risk exposure is reduced. Decisions on on-farm, off-farm diversification and insurance uptake are all interrelated and connected with the farmer's utility and additional variables such as farm and farmer characteristics.

Our goal is to quantify the sign and magnitude, of the relationship between crop insurance and different diversification measures. Based on the framework presented above, we hypothesize that on-farm and off-farm diversification activities are unlikely to have the same relationship with insurance uptake. Crop insurance to cope with climatic risks will probably change the use of other risk management strategies such as on-farm and off-farm diversification activities (Wright and Hewitt 1994). There is a range of literature which suggests that insured farmers are less likely to adopt on-farm diversification, because diversification and insurance are substitutes (O'Donoghue et al., 2009). Insured farmers may increase specialization if it reduces the need for self-insurance (O'Donoghue et al., 2009). Thus, the uptake of insurance may reduce optimal diversification on and off the farm. However, a risk averse farmer using on-farm diversification strategies might also be insured in order to reduce agricultural production risk (Mishra et al., 2004). Since farmers choose income source bundles that optimally balance profit and risk considerations according to their preferences and constraints**,** insurance and diversification activities can have a positive (i.e. complementary) and negative (i.e. substitutive) relationship (Richards 2000, Enjolras et al., 2012).

3. Data

Data collection

This paper is based on an online survey undertaken with 1176 Swiss fruit growers (Knapp et al., 2018). Swiss fruit growers are often characterized by small farm sizes and usually family farms. In our data collected, we have information on a large sample of small producers of special crops, i.e. grapes, plums, berries and cherries.

The data has been pooled as there is little variability in insurance uptake and diversification activities over the three years 2016, 2017, 2018 (see Appendix Table A2 and A3). Specifically, if a farmer is present more than once in the dataset, we use the survey records filed for the first year of her/his participation.

Farmers are asked whether they use crop insurance. In Swiss fruit production, this insurance usually comprises coverage against hail damage as well as coverage against other elementary risks such as storms, landslides and floods (see hagel.ch for details)[1].·For the whole country, this results in a total sum of insured value of about 2 billion CHF with a yearly premium of around 50 million CHF[2]. Farmers in Switzerland can choose to take insurance for a single crop or the entire farm. Crop insurances are prolonged for the next year if the farmer does not cancel it by the end of September. A list of the crops that are chosen by farmers should be sent to the insurance company before the end of April (see www.hagel.ch for more information). The Swiss case is particularly interesting for three reasons: a) Switzerland is considered to be one of Europe's hail hotspot (Schemm et al., 2016), b) Switzerland has a high share of special crops that are vulnerable to hail[3], c) whereas in many countries, agricultural insurances are subsidized (Moschini and Hennessy 2001), Switzerland has currently no subsidies on insurance premiums allowing for an unbiased analysis (Finger and Lehmann 2012).

[1] We also asked more details about different types of insurance, e.g. on insurance of frosts risks. But in general, only few producers deviated from stand contracts. Thus, we here focus on one binary adoption decision: crop insurances yes or no.

[2] Numbers are taken from this source https://www.gabot.de/ansicht/schweizer-hagel-anspruchsvolles-schadensjahr-402989.html.

[3] The total acreage under fruits in Switzerland is circa 6258 ha. Of this area under fruits, cherries are grown on 9%, plums on 4% and table grapes on 0.29%. Grapes cultivated for wine production cover 14712 ha (for more information see: Swiss Federal Office for Agriculture (FOAG) Obst- und Tafeltraubenanlagen der Schweiz 2019, Bern (2019). The production of fruit and grapes for wine production represented 4% and 7% of the total agricultural production value in 2018 (see Knapp et al. 2019).

The dataset includes an overview of fruit varieties (36 berry varieties, 20 cherry varieties, 13 plum varieties and 30 grape varieties) and the surface area for each variety. We create a Shannon Diversity Index[4] to represent the evenness and diversity in the type of fruit varieties used per fruit grower (see Smale, 2006). The Shannon Diversity Index is maximal if the same acreage of all species considered are grown on a farm. Thus, the maximum value differs across crops ranging from 3 (cherries) to 2.25 (plums). Information was collected on further different types of on-farm/off-farm management strategies (1/0) adopted by the fruit growers. These included commonly adopted strategies, such as processing and direct marketing activities, agro-tourism, creation of financial reserves, off-farm investments, forestry work, and share of off-farm income[5]. These diversification activities are relevant to the Swiss case study and were identified based on expert interviews.

As control variables we use farmers' risk preferences, based on a self-assessment of risk as proposed by Dohmen et al., (2011), farm size (100 square meters), focus of the farm, land tenure, production system, the travel distance in seconds to the next urban center[6], farm-specific annual average temperature and annual rainfall derived from high-resolution gridded maps for the period 1961–2016 (Frei and Schär 1998, Frei 2014). Unfortunately, due to the structure of our data, we are unable to estimate short term impacts[7] of within season weather shocks on climate risk management. As the main risk covered in the crop insurance is hail, we also account for both spatial and temporal heterogeneity of hail risk exposure. To this end, we control for hail events in recent years and also include an indicator for long-term hail risk exposure of each municipality (Finger and Lehmann, 2012). Table A4 of the Appendix provides a detailed description of the variables.

Summary statistics

Table 1 provides an overview of some important variables. Table 2 provides summary statistics. In our sample of fruit growers, 37% (436 fruit growers) have an insurance. This reflects that the share of adopters is lower than for the general sample of farms in Switzerland (e.g. Finger and Lehmann (2012), with reported uptake rates of about 60% of farms in the bookkeeping dataset for the year 2009). As shown in Table 2, the mean for the diversification activities varies between insured and uninsured farmers, especially for the Shannon Diversity Index, processing and direct marketing, forestry work and the share of off-farm income. We undertook the Mann Whitney test to compare the means of insured as well as the chi square test for the binary variables.

4. Methodology

Our interest focuses on the relationship between insurance uptake and inter-varietal diversity, processing and directing marketing of produce on the farm, agro-tourism, creation of financial reserves, forestry work, off-farm investments and the share of off farm income. We regress these diversification activities on insurance uptake, accounting for several control variables. Specifications are estimated for every individual diversification activity. In addition, we estimate a specification including all seven diversification activities to test whether the initial coefficient changes.

We estimate specifications without control variables to test the sensitivity of the estimates when control variables are included. The Variance Inflation Factor is calculated to test for multicollinearity between variables. In addition, we calculate correlation coefficients between diversification activities and insurance uptake to check if there are high correlations between these activities. Furthermore, diversification activities were summarized in one indicator to see if the resulting interaction effects are relevant.

A probit model was chosen for our main analysis.[8] , We estimate the variations of the following equation:

$$Insurance_i = \beta_0 + \beta_1 Shannon_i + \beta_2 Process.dir.market_i + \beta_3 Agrotourism_i + \beta_4 Create.fin.reserves_i + \beta_5 Forestry_i + \beta_6 Invest.off.farm_i + \beta_7 Share.off.farm_i + \beta_8 X_i + \tau + \theta + \varepsilon_i \quad (1)$$

$Insurance_i$ indicates whether or not the farmer has crop insurance, $Shannon_i$ is the inter-varietal diversity (i.e. Shannon Index), $Process.dir.markt_i$ is a dummy variable for processing and direct marketing, $Agrotourism_i$ is a dummy variable indicating whether the farmer offers agro-tourism on the farm, $Create.fin.reserves_i$ indicates the creation of financial reserves, $Forestry_i$ is forestry work, $Invest.off.farm_i$ is off-farm investment not related to agriculture, $Share.off.farm_i$ is the share of off-farm income, X_i is a vector of control variables including risk preferences, organic farming, specialization of farm, farm size, land tenure, weather variables (precipitation, temperature, hail events), distance to the next center, τ are production fixed effects (berries, cherries, plums and grapes), θ are period fixed effects (2017 and 2018) and ε_i is the residual term. Moreover, β_0 is a constant, β_1 , β_2 ,β_3, β_4, β_5, β_6, β_7 identify the relationship between insurance uptake and diversification activities, respectively, and β_8 controls for the influence of control variables. The standard errors are clustered at the cantonal level, reflecting possible structural differences in extension and organization of producers. Clustering at the cantonal level, which is a sub-national geographic boundary level in Switzerland, allows for correlation between

[4] To calculate the Shannon Diversity Index, we took the area of parcel i planted with variety j divided by the total area of the parcel i multiplied by the log area share (αji). This was performed for every variety the fruit grower has and the sum of these values results in the Shannon Index. See formula, Shannon Diversity Index : $-\sum \alpha_{ji}/\alpha_i * ln\alpha_{ji}/\alpha_i$

[5] If the percentage of earnings originating from farm is ≤ 50% then 0 if percentage of earnings originating from farm greater than 50%,then 1). We performed the regression with the categorical variables: 0–25%, 26–50%,51–75%,76–100%. Results are available in the Appendix in Table A7.

[6] Urban center is defined here as centers having more than 10′000 inhabitants. The data is taken from google maps.

[7] In case a dataset with more temporal heterogeneity in the risk management decision, i.e. hail insurance and diversification, becomes available, future research could further assess the impact of short term weather fluctuations, i.e. weather shocks, on risk management decisions. Unfortunately, due to the structure of our data we are unable to quantify this impact here.

[8] Our results do not change when using logistic or OLS regression.

Table 1
Overview of variables.

Variables	Data collected
Shannon Diversity Index	Shannon Diversity Index for varieties represents the evenness and diversity of the varieties the fruit grower has. We use the surface area for each variety and calculate a Shannon Diversity Index for each fruit grower (0 = low diversity).
Processing and direct marketing of products	Processing and direct marketing are defined as processing the fruits or selling them directly to the customers (1 = yes, 0 = no).
Agro-tourism	Other activities on the farm such as agro-tourism (1 = yes, 0 = no).
Creation of financial reserves	Creation of financial reserves is defined as saving money for bad periods (1 = yes, 0 = no).
Forestry work	Forestry work is defined as undertaking forestry work (1 = yes, 0 = no).
Off-farm investment	Off-farm investment is defined as investing in other companies or real estate (1 = yes, 0 = no).
Share of off-farm income	Share of off-farm income is 1 if<50% of earnings originate from farm and 0 if more than 50% originates from farm.
Risk preferences	Mean of fruit growers risk aversion over four domains: agriculture, production, market and price, external financing. Likert scale : 10 = not willing to take a risk, 0 = very willing to take a risk.
Organic farming	Production system is organic or not (1 = yes, 0 = no).
Focus specialized	Focus specialized category indicates the farm type, i.e. whether a fruit is source of main income (i.e. berries, cherries, plums or grapes). (1 = yes, 0 = no):
Farm size	Total farmland in 100 sq meters
Land tenure	Percentage of land leased by the fruit grower (0 if ≤ 50%, 1 if greater than 50%)
Mean precipitation	Mean precipitation is the average annual rainfall over the years 1961–2016 for the municipality (Frei and Schär 1998, Frei 2014).
Mean temperature	Mean temperature is the average annual temperature over the years 1961–2016 for the municipality (Frei and Schär 1998, Frei 2014).
Hail last year	Hail last years is the number of hail events in the year prior to data collection for each municipality. (Finger and Lehmann, 2012).
Hail years	Hail years is the number of years with hail events for each municipality in the period 1961–2004. (Finger and Lehmann, 2012).
Distance	Distance measured in seconds from the location of the fruit grower to the next town /urban center (Data retrieved from Google maps)
Year	Year the fruit grower filled out the survey
Fruit	Type of survey the fruit grower responded to (berries, cherries, plums or grapes)
Cantons	Cantons where the fruit growers are located.

Note: The table above provides an overview of variables considered in our regression analysis and for each it includes a definition and the name of the variable. All variables originate from the surveys undertaken with farmers except for the variables where references are provided.

Table 2
Summary statistics.

Overall N = 1176	Insured N = 436	Uninsured N = 728	All N = 1176
Diversification activities	Mean	Mean	Mean
Shannon Diversity Index (0 = low diversity, 3 = high diversity)	1.05*** (sd = 0.7)	0.88 (sd = 0.8)	0.94 (sd = 0.77)
Processing, direct marketing (1 = yes/0 = no)	0.51***(0.001)	0.41	0.44
Agro-tourism (1 = yes/0 = no)	0.14(0.667)	0.13	0.14
Creation of financial reserves (1 = yes/0 = no)	0.26(0.662)	0.27	0.27
Forestry work (1 = yes/0 = no)	0.016**(0.03)	0.04	0.03
Off-farm investment (1 = yes/0 = no)	0.094(0.495)	0.082	0.086
Share off-farm income (earnings originating from non-farm income ≥ 50% =1 if < 50%=0)	0.24 ***(0.000)	0.42	0.35
Control variables			
Risk preferences (Numeric, 0 = Risk loving, 10 = Risk averse)	5.95 (sd = 2.14)	5.95(sd = 2.29)	5.96 (sd = 2.25)
Organic production(1 = yes/0 = no)	0.06***(0.008)	0.11	0.094
Focus specialized (1 = yes/0 = no)	0.49**(0.108)	0.54	0.52
Land tenure (% of land leased) (≥50%=1 < 50%=0)	0.28(0.351)	0.31	0.3
Farm size (100 square meters)	1689***(sd = 2897)	1007.41 (sd = 2023)	1256.36(sd = 2400)
Mean precipitation (numeric)	1124.58***(sd = 202)	1207.2 (sd = 329)	1176.91(sd = 291)
Mean temperature (numeric)	9.11*** (sd = 1.5)	8.89 (sd = 1.7)	8.98 (sd = 1.64)
Hail years (numeric)	26.28***(sd = 9)	23.5 (sd = 10.6)	24.6 (sd = 10)
Hail last year (numeric)	1.5**(sd = 1.4)	1.82 (sd = 1.7)	1.7 (sd = 1.7)
Distance (numeric, time in seconds)	918.99***(sd = 770)	985.82 (sd = 682)	961.63 (sd = 714)

Note: *,**,*** denote significance at the 10%, 5%, 1% level of the Mann Whitney Test highlighting whether there is a significant difference between the two means insured and non-insured. In brackets are the p values of the Chi square test (undertaken only for the binary variables) comparing the insured to non insured mean values.

observations within one canton, thus also spatial autocorrelation. Additionally, as we pool observations from different years, correlation of observations within one canton over the years is also allowed. Clustering the error terms, i.e. also allowing for spatial autocorrelation, affects the standard errors of our regression estimates and therefore the significance of our results. In addition, given

Table 3
Marginal correlation results insurance probit: Specification 1–8.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Diversification activities								
Shannon Index	0.13*** (95% CI: 0.06, 0.2)							0.10** (95% CI: 0.02,0.18)
Processing and direct marketing		0.11*** (95% CI: 0.05,0.16)						0.07*** (95% CI: 0.02,0.12)
Agro- tourism			0.05 (95% CI: −0.04,0.14)					−0.01 (95% CI: −0.08,0.06)
Creation of financial reserves				−0.05 (95% CI: −0.15,0.04)				−0.08** (95% CI: −0.16,−0.00)
Forestry work					−0.23*** (95% CI: −0.29,−0.15)			−0.23*** (95% CI: −0.33,−0.12)
Off-farminvestment						0.02 (95% CI: −0.13,−0.17)		−0.02 (95% CI: −0.14,0.11)
Share of off-farm income							−0.17*** (95% CI: −0.25,−0.08)	−0.13*** (95% CI: −0.19,−0.07)
Control variables	Risk preferences, organic production systems, focus specialized, land tenure, farm size, mean precipitation, mean precipitation squared, mean temperature, mean temperature squared, hail years, hail last year, distance							
Mcfadden R^2	0.128	0.117	0.109	0.110	0.108	0.123	0.123	0.150
Mcfadden Adjusted R^2	0.096	0.085	0.077	0.078	0.076	0.086	0.088	0.103
Number observations	881	881	881	881	881	787	787	787
AIC*n	1080.304	1093.251	1102.539	1101.619	1103.381	1103.381	974.655	948.581
BIC*n	1171.144	1184.091	1193.379	1192.459	1194.221	1194.221	1063.351	1041.946
Deviance	1042.304	1055.251	1064.539	1063.619	1065.381	1065.381	936.655	908.581

Note: Estimation method with a probit regression with the dependent variable insurance use (1/0). Coefficients are marginal correlations. Confidence intervals (95%) are in parenthesis. *,** and *** denote significance at the 10%, 5% and 1% level. Standard errors are clustered at cantonal level. On-farm diversification activities (except for the Shannon Index) and off-farm diversification activities are dummy variables.

our relatively small number of clusters, i.e. there are only 26 cantons in Switzerland, we use the wild bootstrap to compute standard errors (Cameron et al., 2008).

The Oster bounds (Oster 2019) approach and the Generalized Sensitivity Analysis of Imbens (2003) serve as robustness tests. The Oster bounds analysis (Oster 2019) indicates whether coefficients for significant variables are robust against omitted variable bias. The Generalized Sensitivity Analysis of Imbens (2003) quantifies the extent of the bias which would result from the absence of each of the control variables included in our analysis.

5. Results

Table 3 summarizes our main results. Columns 1–7 present the results of the restricted specifications for every diversification measure independently. Column 8 shows the full specification with all diversification measures included.

We find that there is a pattern:

i) On-farm diversification activities are positively associated with insurance uptake, except for the creation of financial reserves
ii) Off-farm diversification activities are negatively associated with insurance uptake
iii) Farmers with higher financial reserves are less likely to buy an insurance.

As can be seen in column (1) and column (8), the Shannon Index is positively and significantly associated with insurance uptake. A one-unit increase in the Shannon Index (increased inter-varietal diversity), ceteris paribus, is associated to a 10 percentage points increase in the probability that a farmer has an insurance. Column (2) and column (8) indicate that processing and direct marketing is positively and significantly associated with insurance uptake. There is a 7 percentage point (column (8)) higher likelihood that farmers who process and market their products directly will have insurance. This highlights that the Shannon Index and the processing and direct marketing of farm produce are complements to insurance uptake. As shown in column (3) and column (8), the coefficient for agro-tourism is not statistically significant. Creation of financial reserves is not statistically significant in the restricted specification (column 4), but it gains significance in the full specification in column (8). Farmers who create financial reserves are 8 percentage points (column 8) less likely to have insurance.

Column (5) illustrates the restricted specification for forestry work. The coefficient for forestry work remains the same in the full specification (8). Farmers who undertake forestry work are 23 percentage points less likely to have an insurance. As shown in column (6), off-farm investment is not statistically significant in the restricted specification and this also applies to the full specification (8) where off-farm investment is likewise not statistically significant. Finally, as shown in column (7), the share of off-farm income is negatively associated with insurance uptake and is also statistically significant and negatively associated with insurance uptake in column (8) of the full model. Farmers who have a higher share of off-farm income are 13 percentage points less likely to have an insurance.

As can be seen in Table 3, control variables are included in all presented models (see Appendix Table A6 for marginal effects of control variables). When performing the full specification without control variables, the coefficients were similar in sign, magnitude and significance (see Table A6). In another sensitivity tests, we ran OLS, logit regressions and OLS regression with wild boot cluster (see Appendix Table A8-A10, Table A13)[9] and found no differences in results. In addition, Table 3 shows that the coefficients which are statistically significant in the restricted specification remain statistically significant in the full specification, which demonstrates the robustness across various specifications of the results presented here.

As a robustness check, we use a cluster analysis to find potential interrelations between the different diversification strategies. The results are to be found in the Appendix (see Table A12) and indicate that certain diversification measures tend to be adopted in bundles more often than others, namely i) processing and direct marketing and agro-tourism, ii) creation of financial reserves and off-farm investment, iii) work off-farm and agro-tourism. Since these results indicate slight interactions between the activities themselves, we use the Variance Inflation Factor to show that our main set of results, i.e. the regression analysis is not affected by multicollinearity. The Variance Inflation Factor is below 2 and the correlations between diversification activities are ≤ 0.3 (see Appendix Table A10-A11, Fig. A1). Therefore, we conclude that our results on the relation between the different diversification strategies and the hail insurance uptake are unaffected by potential correlations between the diversification strategies itself.

The results of an Oster bounds analysis (Oster 2019) indicate that all significant coefficients are quite robust and selection on unobservables would need to be at least twice as important as selection on observables to meaningfully change our results (see Appendix, Table A14).

The Generalized Sensitivity Analysis (see Appendix, Figure A2) based on Imbens (2003) and Harada (2013) quantifies the extent of the bias that would result from the absence of each included covariate, thus allowing the researcher to consider the plausibility of the existence of actually omitted confounding variables with the same effect. The plotted contour shows at which point such confounding variables would have the potential to meaningfully change our results. In our study, selection is not indicated to be a first order issue (see Appendix, Figure A2).

[9] Results of correlation show low collinearity between the on-farm/off-farm management strategies variables. We assess multicollinearity with the general variance of inflation factor for categorical variables and the variance inflation factor for the continuous variables chosen for our specifications (see Appendix, Table A9-A10).

6. Discussion

Our analysis sheds new light on farmers' management of climate risks. More specifically, we revisit the relationship between crop insurance use and diversification, on and off the farm. The here considered diversification strategies can all be used to reduce weather risks on the farm. For instance, the inter-varietal diversity is a way for the farmers to spread the growth period of different fruit varieties over the year. Other diversification strategies which we include here are off-farm strategies, such as forestry work, reducing the exposure of the general income (including all off- and on-farm activities) to weather risks.

Our results highlight the value of breaking down diversification activities instead of bundling them into one single index, as there is a tendency towards a positive association between on-farm diversification activities and insurance uptake while the association between off-farm activities and insurance uptake tends to be negative. Our results reveal one exception to this pattern, namely the creation of financial reserves. In fact, saving money for bad times follows the off-farm diversification pattern and is negatively correlated with insurance uptake. Note that saving money for bad times is not a clear-cut on– or off-farm diversification activity, as the money saved can be used for purposes other than agricultural activities. Money itself is directly accessible to the farmer, whereas this is not the case with processing and direct marketing. In addition, resources saved could technically also be shifted out of agriculture. This is further suggested by the results of the cluster analysis performed, which identifies that off-farm investment and creation of financial reserves are part of the same cluster. We presume that farmers who build up financial reserves are saving money for off-farm investments.

Farmers choose diversification strategies from a range of portfolios. There is clear evidence that farmers may still be insured even if they pursue diversification activities on the farm. Our results highlight that policies encouraging insurance uptake will not necessarily have a negative impact on diversification on the farm. Diversification itself is an important strategy for farms, especially in Europe as it not only enhances the farms' social cohesion, but is also strongly linked to their multifunctionality (Van der Ploeg and Roep 2003, Boncinelli et al., 2017, Weltin et al., 2017). We find a positive association between inter-varietal diversity and insurance uptake. In current literature, crop diversity or species diversity is associated negatively with insurance. In their study on Italy, Di Falco et al., (2014) state that diversification of crops (i.e. monoculture vs. diversified crops) is negatively correlated with insurance. However, the context of our case-study must be considered, as we analyze extreme events such as hail. Enjolras and Sentis (2011) show that while insurance can act as a substitute for less diversified farms, it can also be seen as a complement when facing major hazards. Single hazard events, such as hail, constitute high impact but often low probability losses (Bocquého et al., 2014). Farmers might overestimate this risk and thus take an insurance (Bocquého et al., 2014). Consequently, although farmers go in for on-farm diversification to manage risk, they still rely on a crop insurance in this context. In addition, extreme events are predicted to increase due to climate change. This might also motivate farmers to have insurance in spite of their diversification activities (Botzen et al., 2010). Finally, it is important to highlight that in addition to its effects on risk management, varietal diversity may provide other private and public benefits, such as lower pest pressure and other ecosystem services (Baumgärtner 2007, Di Falco et al., 2014; Schaub et al., 2020). Thus, risk management strategies may not be the only motivation for fruit growers in our sample to go in for inter-varietal diversity.

Entrepreneurial literature indicates that processing and direct marketing can be regarded as a risky activity. Farmers face a number of challenges when establishing a new business model. They must identify their available resources and products, as well as customer requirements (Ferguson and Hansson 2015). Thus, given the riskiness of this business, farmers might also decide to take out an insurance to reduce the risk. From a moral hazard perspective, insured farmers might decide to go in for more risky diversification activities, such as processing and direct marketing. On the other hand, diversification is usually perceived as risk decreasing. To contextualize our results, we suggest that although processing and direct marketing is considered as a diversification activity, in the case of farmers who focus on fruit production, it is rather more closely related to the production of fruit on the farm. Assuming that farmers process fruit, the harvest might not be available for this diversification activity if it is damaged by hail. Given that this activity relies on the farm's own produce, it might explain the positive correlation with insurance uptake. Along these lines, Mishra and Goodwin (2003) suggest that farmers who earn most of their income from farming activities are more likely to be insurance users.

There is a close relationship between our research and studies that identify the determinants for insurance uptake. For example, this literature puts forward that off-farm income diversifies a farm's income and thus reduces the probability that a farmer will take an insurance, given that these farmers have more self-insurance possibilities (Mishra and Goodwin 2006, Velandia et al., 2009). In the context of on-farm, off-farm diversification activities and insurance uptake, it is important to note that insurance uptake deals with yield risk, while diversifying per se deals with income risk, of which yield risk is a component (Blank and McDonald, 1996). Note that in the case of crop insurance, there exists an alternative hedging instrument for hail risk for some types of crops, for example hail nets (Rogna et al., 2019) which we did not include in our study. However, hail risks remain even if using hail nets (e.g. Gandorfer et al., 2015)). In fact, in Switzerland insurance contracts incentivize the combination of nets and insurance by offering lower premiums. Thus, these are often used in combination. Off-farm management strategies reduce the variance of the total farm income as these income sources are independent of weather and hail (Finger and Lehmann 2012). Our results indicate that off-farm diversification activities tend to be negatively correlated with insurance uptake. However, it can go both ways, namely the fruit grower has off-farm activities and therefore he/she decides not to take an insurance, or it is impossible for the fruit grower to take an insurance due, for instance, budget constraints and decides to pursue off-farm activities to meet the risk.

7. Conclusion

In this paper, we analyze a rich dataset from 1176 Swiss fruit growers and investigate the relationship between insurance uptake and various diversification strategies, namely, inter-varietal diversity, processing and direct marketing of the produce, agro-tourism, creation of financial reserves, forestry work, off-farm investment and share of off farm income. The hail insurance but also the diversification activities contribute to manage climate risks of farmers. Hail insurance is the dominant insurance type in Swiss and other central European crop production, so that quantifying its interrelation with other risk management strategies is crucial to understand farmers' climate risk management decisions, and subsequently to develop targeted policies. We include a vector of control variables with farm and farmer characteristics, risk exposure and weather data. Up until now, literature rates insurance as a replacement to diversification measures and sometimes as a complement to diversification measures. In this paper, we revisit this relationship by considering different types of management strategies, namely both on-farm and off-farm diversification activities, adopted by fruit growers in Switzerland.

Our results show that on-farm activities are positively correlated with insurance uptake and are thus complementary risk management strategies for farmers, while off-farm activities have a negative correlation with insurance uptake, and thus represent substitutes in a farmer's risk management portfolio.

For policy makers, our findings show that interdependencies between risk management strategies must be taken into account when providing support for such strategies. If more successful policies are to be developed, it is essential to understand the association between different diversification activities and insurance uptake and indeed to recognize that the associations themselves differ depending on the type of diversification activity. For example, support for both on-farm diversification and insurance might be efficient because both are substitutes. Along these lines, this could also mean that insurance does not necessarily reduce varietal diversity on farms. In turn, this suggests that insurance does not per se hinder optimal diversification on the farm. Moreover, insurance providers must understand how diversification activities relate differently to insurance uptake as it may help them design insurance for farmers who are currently not well served by the products on offer. We suggest that insurance providers may need to develop tailored options for farmers who rely on off-farm income.

In addition, the types of strategies chosen by farmers will have a certain impact on the structure of the farming sector in future. When incentivizing insurance or the use of other on-farm and off-farm diversification strategies, policy makers should allow for the interdependencies, e.g. pay attention to farmers' responses to avoid contradictory policy instruments.

Future research should seek to further probe the generality of our results. In particular, the interplay of crop and inter-variety diversity and the associated ecological benefits, as well as different crop insurance schemes merit more attention. Moreover, observed diversification strategies and insurance uptake across different types of farm production must be investigated to test whether different patterns emerge.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crm.2021.100315.

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