Catastrophic weather events and (subsidised) crop insurance markets. Evidence from Italy

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Abstract

Catastrophic (CAT) weather events are rare and impactful, yet still poorly considered in *ex-ante* risk management policy interventions. Subsidised crop insurance schemes are not an exception, although the systemic nature of those risks has cascading effects that are reflected on the entire food systems and along the value chains. The Italian subsidised crop insurance market, and its dynamics vis-à-vis

CAT events, including flood, drought, and frost, is an interesting case study. Insurance uptake and coverage increase after CAT shocks, signalling their value in strengthening farmers resilience to climate changes. The responsiveness is higher when coverage is predominant, with markedly heterogeneous patterns calling for deeper understanding of the trade-offs that are put in place by these policy instruments, central in the EU risk management strategy.

Keywords: *Agriculture; Climatic risk; Extreme event; Risk management; Subsidised insurance.*

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Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Introduction

Since 2010, more than eight droughts, fifty-one frost events and one hundred fifty severe floods[1] have damaged the EU agricultural sector, particularly vulnerable to extreme weather events (e.g., Chavas, 2019; Boysen et al., 2023; Bozzola et al., 2023). These shocks generate cascading impacts along the value chains, challenging the resilience of European agri-food systems. The exposure will be even higher (e.g., IPCC, 2023) with an increasing occurrence of extreme (potentially catastrophic) events, whose compounding effects under climate change constrain both private and public risk management responses.

Coping *ex-post* is costly and cannot be predicted. Emblematic cases have been observed in in Italy, France, and Germany[2], where the public expenses for *ex-post* compensation have rapidly become unsustainable. This highlights the limits of crisis-driven responses and the need for forward-looking, evidence-based strategies to prevent and manage systemic risks. The shift from an *ex-post* to an *ex-ante* planning approach is further reinforced by the EU's risk management framework under Regulation (EU) 2115/2021, which governs the implementation of the Common Agricultural Policy (CAP) for the 2023-2027 period. This Regulation strengthens preventive risk management instruments[3] and allocates approximately 2.7 billion EUR to support at least 15 percent of EU farmers[4], in line with broader EU objectives to enhance resilience and climate adaptation capacity in agriculture.

Started to help coping with frequency adversities, the insurance schemes have potential for extreme (named hereafter 'catastrophic') adversities. Nonetheless, the extent to which the occurrence of catastrophic (CAT) events (i.e., flood, drought, and frost) drives crop insurance uptakes is an (unanswered) empirical research. Understanding whether and how insurance responds to CAT events is crucial to assess the effectiveness and coherence of climate adaptation policy tools. Is the uptake of subsidised crop insurance responsive to CAT events? How to move forward to widen participation? Eliciting the CAT events-uptakes nexus (in subsidised crop insurance schemes)[5] is challenging: the Italian case is an ideal one for at least three reasons. First, Italy is among the largest EU agricultural producers in terms of production value and is increasingly exposed to (extreme) weather risks[6], a major driver of crop yield volatility (e.g., Bucheli et al., 2023; Severini et al., 2025). Such exposure exemplifies how climate-related hazards may act as systemic risks, with differentiated impacts across crops, regions, and supply chains. The frost events occurred in Europe (e.g., April 2017) caused large economic losses, especially in the fruit and wine sectors. The expenses are very high in Italy, France and Germany: the Italian expenditure has been about 1 billion EUR in 2017 (Faust and Herbold, 2018), and it is still very high (in 2023 about 213 million have been devoted to *ex-post* compensations of weather-related losses). The flood event that hit the Emilia Romagna region in May 2023 implied economic losses for the agricultural sector as high as 1.5 billion EUR (Agrisole, 2023).

Second, with a public expenditure of more than 2 billion of euro between 2014 and 2020 (ISMEA, 2022), Italy is a top EU country for crop insurance[7] and compensatory measures, reaching 213 million in 2023 (Corte dei Conti, 2023). The current subsidised crop insurance portfolio includes schemes against frequent and low impacts events (e.g., hail, intense wind, heavy rain, excessive snow) or rare, catastrophic perils (e.g., flood, drought, frost) (e.g., Santeramo et al., 2022). The weather risk exposure and changes in political interventions makes Italy a paradigmatic case study to understand whether the uptake of subsidised crop insurance is responsive to CAT events. This diversified policy mix offers a valuable setting to assess complementarities, trade-offs, and coherence between risk management and climate adaptation instruments.

Third, the insurance market is highly heterogeneous, confined to a few geographical areas and crops (e.g., ISMEA, 2020), but open to new solutions for risk management, such as the experimental weather index insurance schemes[8] and the more recently established Agri-CAT Fund, a National Mutual Fund to cover losses induced by CAT events[9]. This heterogeneity allows us to explore leverage points for improving resilience and participation in underinsured regions. The characteristic structure of the Italian insurance market favours the identification of solutions to move forward to widen participation in the subsidised crop insurance.

The literature investigating the role of CAT adversities in driving the uptake of crop insurance[10] is mainly focused on the US (Yu and Goh, 2022; Aglasan et al., 2023; Liu and Ramsey, 2023). Notably, Di Falco et al. (2014) investigate farmers' demand for insurance in relation to a larger exposure to weather risks. While weather risks increase participation, the effects on coverage have not (yet) been investigated in the EU. Moreover, deriving evidence-based policy recommendations requires a close fit of the empirical analyses to the intervention tool under investigation. Di Falco et al. (2014) show that temperatures and rainfall may drive insurance uptake. These events are not the target of the EU policy. Moreover, robust evidence is needed to inform policy design under evolving climate conditions and to assess how adaptation tools perform across different risk profiles. We focus on CAT events that are exactly addressed by the novel policy instruments.

This paper stands out for two clear motivations. First, we close the knowledge gap on the role of CAT events in crop insurance uptake: our results clearly indicate they have spread insurance and increased coverage. Second, we contribute to evidence-based policy making by providing insights relevant to the design of resilient, coherent, and fair climate adaptation strategies in agriculture. Farmers' responsiveness to CAT events, strengthens the need to offer tailored schemes for areas where participation is scant.

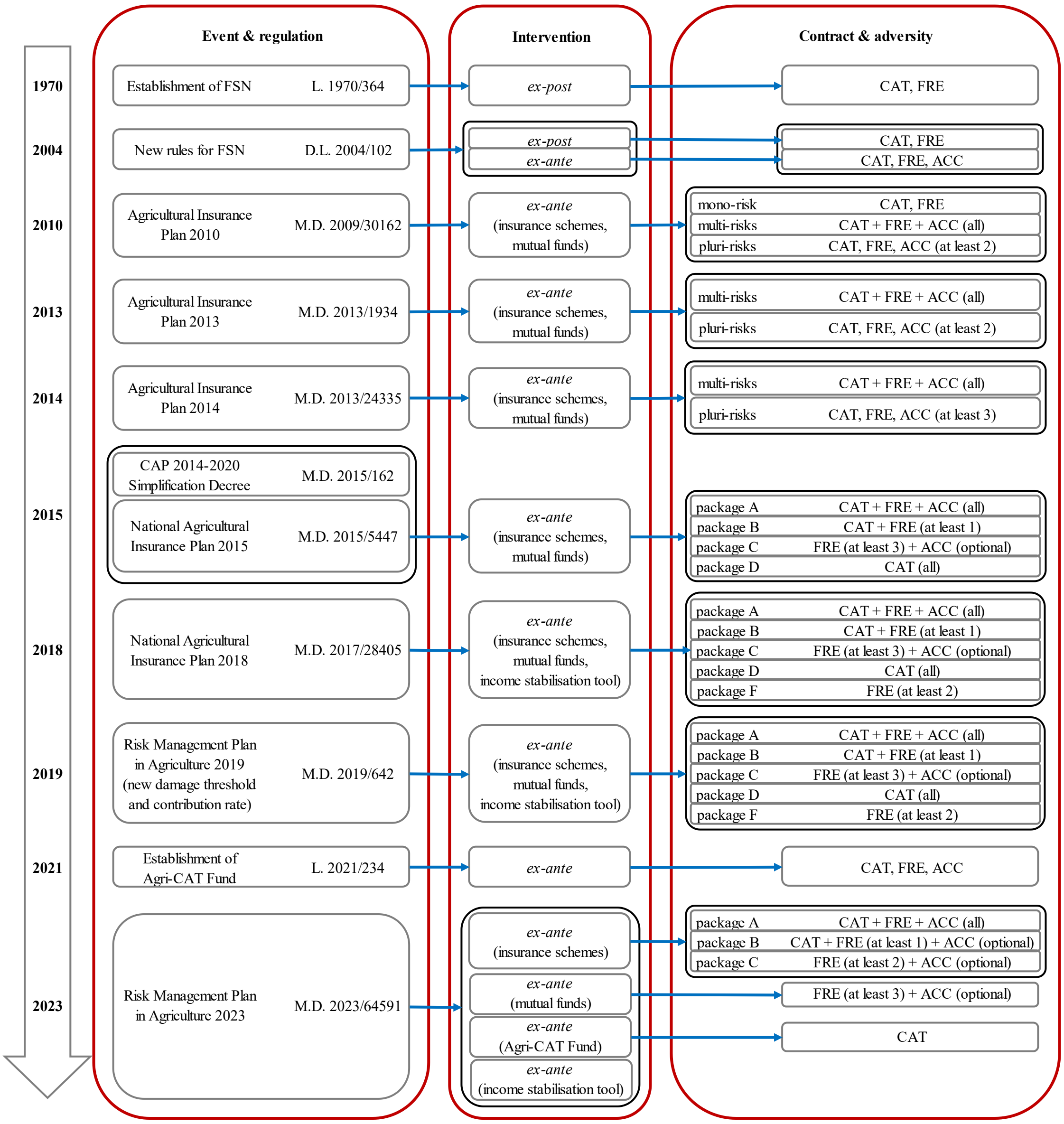
An evolving policy framework

The support to risk management in agriculture has a long tradition, and in Italy it has recently undergone several changes in line with the development of the EU framework for risk management[11] (figure 1). The public intervention supports farmers exposed to (via *ex-ante* measures) or affected by (via *ex-post* measures) the adverse effects of natural disasters or exceptional events. These include: (i) CAT adversities (i.e., infrequent perils) such as flood, drought, frost; (ii) frequency adversities (i.e., frequent perils) such as hail, intense wind, heavy rain, excessive snow; (iii) accessory adversities (i.e., other perils) such as sunstroke and warm wind, temperature leap.

In 1970, the EUSF (in Italy named Fondo di Solidarietà Nazionale, FSN) was established to support farmers affected by hail, frost, and other adverse weather events, through compensatory measures (Law No. 364/1970). The Legislative Decree No. 102 of March 29, 2004 (implementing Regulation (EC) No. 659/1999) established new rules for the functioning of the FSN. Financial interventions in support of farms included both *ex-post* and *ex-ante* measures, the latter in the form of insurance premium subsidies and contributions to mutual funds. Since the Agricultural Insurance Plan 2010 (Ministerial Decree No. 30162 of December 22, 2009), mono-risk[12], multi-risks, and pluri-risks insurance contracts were introduced to offer coverage against, respectively, one adversity (catastrophic or frequency), all adversities (CAT, frequency, and accessory), and two or more adversities[13] (free combinations of CAT, frequency, accessory).

The supply of insurance contracts has been expanded with the National Agricultural Insurance Plan 2015, when more flexible contracts, the so-called 'packages', substituted multi- and pluri-risks contracts (Ministerial Decree 5447 of March 10, 2015, implementing Regulation (EU) No. 1305/2013). The packages provided coverage against all adversities (package A), CAT adversities and at least one frequency adversity (package B), at least three frequency adversities and, optionally, accessory adversities (package C), all the CAT adversities (package D). The National Agricultural Insurance Plan 2018 introduced a further insurance contract covering at least two frequency adversities (package F) and provided financial support to the Income Stabilisation Tool (Ministerial Decree No. 28405 of November 06, 2017).

Figure 1. Timeline for the evolution of the support to risk management in agriculture for weather risks in Italy.



Notes: Acronyms are '*Fondo di Solidarietà Nazionale*' (FSN), Risk Management (RM), Common Agricultural Policy (CAP), catastrophic adversities (CAT), frequency adversities (FRE), accessory adversities (ACC).

Since 2013, insurance schemes and mutual funds against adverse weather events started to receive financial support from both the First Pillar (through direct payments) and the Second Pillar (through the Measure 17 of the Rural Development Programme) of the Common Agricultural Policy (CAP) (Regulation (EU) No. 1305/2013). The CAP 2014-2020 Simplification Decree introduced these changes in the national policy framework (Ministerial Decree No. 162 of January 12, 2015). To face the consequences of a growing number of adverse weather events, in 2017, the EU strengthened the support to risk management tools by lowering (from 30 percent to 20 percent) the damage threshold which trigger the access to subsidies and increasing (from 65 percent to 70 percent) the public contribution rate (Regulation (EU) No. 2393/2017). These changes have been effectively implemented starting with the Risk Management Plan in Agriculture 2019 (Ministerial Decree No. 642 of January 21, 2019).

Recently, a National Mutual Fund (named Agri-CAT) has been established to compensate the damages caused by CAT events (Law No. 234/2021 implementing Regulation (EU) No. 2115/2021). The Agri-CAT Fund provides, to all farmers receiving direct payments, a basic mutual coverage to cope with losses greater than 20 percent of the historical production, caused by flood, frost, and drought. The aim is taking preventive action while encouraging the uptake of insurance contracts. The Risk Management Plan in Agriculture 2023 (Ministerial Decree No. 64591 of February 08, 2023) establishes criteria and methods of intervention of the Fund which has started in 2022 with an experimental phase and a budged of 50 million EUR. The Plan has reshuffled the supply of insurance contracts. For insurance schemes, the package A (i.e., all adversities) has been maintained and the package D (i.e., all CAT adversities) has been dismissed; the package B, earlier offering coverage against CAT adversities and at least one frequency adversity, now may optionally include also accessory adversities; the packages C and F have been merged and the new package C includes at least two frequency adversities and optionally accessory adversities.

Empirical specification

We outline a simple conceptual framework explaining the crop insurance uptake as a function of CAT events (see Supplementary Material, Section A). Expected insurance decisions are formed from past realisations of yields, premia, and paid indemnities (e.g., Deryugina and Kirwan, 2018; Landry et al., 2021; Turner and Tsiboe, 2022)[14] and negative events, such as the CAT events[15] (e.g., Santeramo et al., 2022; Bucheli et al., 2023). The (expected) insurance supply is also function of insurance premium[16]. Clearance conditions imply that, *ceteris paribus*, shifts in CAT events alter market equilibria, as reflected by coverage levels.

Denoting provinces with $i \in I \equiv \{1, \dots, I\}$ and crops with $k \in K \equiv \{1, \dots, K\}$, the (unrestricted, Ω) empirical specification is as follows:

$$S_{ikt} = \alpha_k + \beta Y_{ikt} + \gamma P_{ikt} + \psi \boldsymbol{W}_{it} + \varepsilon_{ikt} \qquad (1)$$

where S_{ikt} represents the share of insured value of production of crop k in province i at time t[17] and ε_{ikt} is the error term. The crop-specific constants, α_k, proxy the level of insured value for crop k[18]. These constants, coupled with the inclusion of time and geographical fixed effects in robustness checks, allows us to explicitly address unobserved heterogeneity. The terms Y_{ikt} and P_{ikt} denote, respectively, the yield and the insurance premium of crop k in province i at time t. This set of structural and policy-related control factors (α_k, Y_{ikt}, P_{ikt}) contributes to mitigate omitted variable bias. The parameter β (i.e., $\frac{\partial lnS}{\partial lnY}$) captures the elasticity of insurance demand with respect to yield and is expected to be negative. The parameter γ (i.e., i.e., $\frac{\partial lnS}{\partial lnP}$) stands for the own-price demand insurance elasticity. The higher the γ, the more elastic the insurance demand.

The matrix $\boldsymbol{W}_{it}$ captures CAT events and contains three dummy variables proxying, respectively, the occurrence of flood, drought, and frost in a province i at time t. The three indicators are based on daily weather information and then aggregated at the annual level. The variable for flood takes the value 1 when a daily precipitation larger than 50 mm (Ma et al., 2021) comes after at least 53 mm of precipitations cumulated on previous five days (Diakakis, 2012), and 0 otherwise. We assign nonnull values to variables for drought when the index used to measure the severity of drought (i.e., the 3-months Standardised Precipitation Evapotranspiration Index, SPEI) is lower than -1 (ISMEA, 2023) and for frost when minimum daily temperatures fall below 0 °C (Risk Management Plan in Agriculture 2023, Ministerial Decree No. 64591 of February 08, 2023). For each province, the three indicators equal 1 whether the CAT event occurs at least once in a year. The parameter ψ (i.e., $\frac{\partial lnS}{\partial lnW}$) is the semi-elasticity of insurance demand with respect to CAT events. CAT events are by definition exogenous, limiting the risk of reverse causality. It is expected to be positive: the more frequent the occurrence of CAT events, the higher the insurance demand. When ψ is higher, crops are more homogeneous within a province, which makes the insurance demand more sensitive to the occurrence of CAT events[19].

Our main estimation strategy is based on the Ordinary Least Square (OLS) estimator. Under the assumption that, conditional on the set of controls included in the model, the occurrence of CAT events is exogenous to farmers' insurance decisions, the OLS coefficient can be interpreted as an average treatment effect.

The effects of the CAT events, as internalised by the subsidised crop insurance market, are quantified as difference between the predicted of insurance coverage ($\hat{S}_{ikt}$) in the unrestricted (Ω) and restricted (ω, i.e., assuming $\psi = 0$) model[20].

Data

We use a rich panel of annual data on insurance and production values at the province-crop level, integrated with daily province-specific weather data. Insurance, production, and weather data are respectively from the Institute of Services for the Agricultural and Food Market (ISMEA), the Italian National Institute of Statistics (ISTAT), the Joint Research Centre (JRC) Monitoring Agricultural ResourceS (MARS) Meteorological Database.

The dataset observes all Italian provinces and crops (namely almond, apple, apricot, corn, durum wheat, grape wine, kiwi, orange, peach, pear, tomato)[21] covered by the Agri-CAT Fund over the period 2010-2020.

This is among the few empirical analyses on the nexus between insurance demand and weather risks using highly granular data at the spatial and temporal level. A remarkable exception is the working paper by Citino et al. (2021).

Table 1 presents summary statistics for the main variables used in the analysis. On average, the share of insured production value is low (1.41%), with substantial dispersion across observations, indicating heterogeneous insurance uptake. Premiums are modest on average (0.01 million EUR) and average yields amount to 17 t/ha, with considerable variability reflecting differences across crops and regions. Among weather-related risks, drought and frost are relatively frequent, affecting 11% and 8% of observations, respectively, while flood events are rare.

Table 1. Descriptive statistics of catastrophic weather events in 2010-2020.

Variable	Unit	Mean	Std. Dev.	Min	Max
Share of insured value of production	-	1.41	4.07	0.00	100.00
Premium	Million EUR	0.01	0.08	0.00	2.68
Yield	t/ha	17.05	15.73	0.01	125.00
Flood	-	0.00	0.02	0.00	1.00
Drought	-	0.11	0.31	0.00	1.00
Frost	-	0.08	0.28	0.00	1.00

Notes: Descriptive statistics are mean and, in parentheses, standard deviation.

Evidence on the relationship between catastrophic adversities and insurance uptake

Table 2 reports the OLS estimates of the restricted (ω, columns 1a and 1b) and unrestricted (Ω, column 2) models. Column 1a presents the relationship between insurance uptake and CAT events only, while column 1b focuses on the relationship between insurance uptake and the set of control variables. Column 2 reports the full specification, including both CAT events and control factors. Control variables are presented separately from the main variable of interest because they may be simultaneously determined with respect to CAT events; specifications 1a and 1b therefore allow us to isolate their individual associations with insurance uptake. We compute the Owen (column 4) and Shapley (column 5) decomposition of R-squared to assess the relative contributions of CAT events to explaining observed insurance dynamics (Shapley, 1953; Jensen et al., 2018).

The insurance uptake is inversely related to variations in crops' yield and relatively inelastic to changes in insurance premia[22]. These drivers capture most of the variation in the insurance uptake (i.e., 73 percent premium and 23 percent yield). The insured values and the occurrence of frost events correlate. The variables for CAT events are responsible for 3 percent of changes in insurance levels, with frost events capturing 95 percent of the proportion of the model's R-squared attributed to all CAT events.

Our results are consistent with Di Falco et al. (2014) claiming that most studies (e.g., Smit et al., 1996; Dolan et al., 2001) found a positive association between crop insurance uptake and weather experiences. When a CAT event occurs, participants in the insurance market, especially the risk-averse and the most exposed ones, are more willing to increase the insurance and new participants enter in the market. Put differently, exposure to risks is one of the drivers of participation in insurance schemes (Santeramo et al., 2016).

Table 2. CAT events and share of insured value of production.

				Decomposition of R-squared		
	Restricted model (ω)		Unrestricted model (Ω)	Estimates	Owen values (%)	Shapley values (%)
Variables	(1a)	(1b)	(2)	(3)	(4)	(5)
Premium (ln)		0.5491***	0.5437***	0.6370***	73.3291	73.3286
		(0.0839)	(0.0831)	(0.0948)		
Yield (ln)		-1.6334***	-1.6374***	-1.1501***	23.6011	23.6011
		(0.3704)	(0.3660)	(0.1812)		
CAT events					3.0699	
Flood	0.3174		0.4967	0.5727		0.0023
	(0.6181)		(0.5638)	(0.5675)		
Drought	0.2679*		0.2140	0.2059		0.1456
	(0.1500)		(0.1370)	(0.1588)		
Frost	1.0601**		0.9034***	0.8564**		2.9224
	(0.3493)		(0.3305)	(0.3811)		
Constant	1.2845***	0.8367	0.7896	-1.2779*		
	(0.1172)	(0.9270)	(0.9205)	(0.6905)		
Fixed effects	Crop	Crop	Crop	-		
Observations	238,169	238,169	238,169	238,169		
R-squared	0.17	0.26	0.26	0.17		

Notes: Ordinary Least Square (OLS) estimates of the restricted (columns 1a and 1b) and unrestricted (column 2) model. OLS estimates without crop fixed effects (column 3) and related Owen (column 4) and Shapley (column 5) decomposition of R-squared. Dummy variables proxy the occurrence of flood, drought, and frost events. Standard errors, clustered at province-crop level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Robustness checks

The correlation between insured values and the occurrence of frost events is statistically different from zero, and positive. Results are consistent across different specifications (table 3), exception made for the estimates including geographical characteristics, that have larger confidence intervals. Columns (1) and (3) presents the estimates of the unrestricted (Ω, baseline) model and excluding crop fixed effects, respectively (see table 2).

To test for the severity of CAT events, we regress the share of insured value of production against the annual number of flood, drought, and frost events (column 2). The coefficients estimated for flood and drought remain not statistically different and the severity of frost events is still positively correlated with the insurance demand.

Columns (4) to (7) control for different sets of fixed effects. We progressively include year (column 4) and geographical area (column 5) fixed effects. Provinces are grouped into five geographical areas: North-West, North-East, Centre, South, Islands. Annual effects control for exogenous technological progress (e.g., Bozzola et al., 2023). Geographical effects capture unobserved factors generating differences in insurance uptake across provinces, such as similarities in climate conditions of neighbouring provinces, in riskiness and value of productions (e.g., Diffenbaugh et al., 2021). As expected, we find a lower responsiveness to frost events when we rely on variations within narrower geographical areas (0.6713 as compared to 0.9034 of the baseline). The estimate captures the annual change in insurance uptake associated with the occurrence of at least one frost event hitting a representative crop within a geographical area. When controlling for geographical unobserved characteristics, we also detect a positive correlation between insured values and the occurrence of drought events. This result is confirmed in specifications that include more refined spatial effects: i.e., regional (column 6) and provincial (column 7) fixed effects.

Yield and premium are variables traditionally introduced into empirical models to explain the insurance demand (e.g., Goodwin, 1993). However, yields are likely affected by extreme weather events while affecting the insurance demand (e.g., Tappi et al., 2023). To test the robustness of the effects estimated for CAT events, we include the most refined set of fixed effects (i.e., province, crop and year, as in column 7) and exclude yield and premium (column 8). The occurrence of drought events is still positively correlated with the insured values. The coefficients estimated for drought in columns (7) and (8) are not statistically different.

The decision to taking out insurance contracts may be affected by past experiences (e.g. Santeramo 2019). We test whether past yields and weather extremes partly explain the insurance participation choice. We progressively include one-period (column 9), two-periods (column 10) and three-periods lagged yield (column 11). We then substitute yield with historical yield, built as a three-year moving average of yield (column 12). We find that the insured values are not responsive to past yields, but the occurrence of CAT events is still positively correlated with the insurance demand. Similarly, we include one-period lagged CAT events (column 13) and find that the insurance uptake is positively correlated with the current and (to a lower extent) past frost events.

Table 3. CAT events and share of insured value of production: robustness checks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Variables	Baseline	Severity	No FEs	Crop, year FEs	Region group, crop, year FEs	Region, crop, year FEs	Province, crop, year FEs	No controls	One-period lagged yield	Two-periods lagged yield	Three-periods lagged yield	Historical yield	One-period lagged CAT
Premium (ln)	0.5437***	0.4824***	0.6370***	0.5410***	0.5140***	0.4188***	0.4036***		0.4622***	0.4611***	0.4647***	0.4542***	0.5415***
	(0.0831)	(0.0803)	(0.0948)	(0.0849)	(0.0815)	(0.0967)	(0.1119)		(0.0810)	(0.0807)	(0.0818)	(0.0815)	(0.0827)
Yield (ln)	-1.6374***	-1.6683***	-1.1501***	-1.5916***	-1.8572***	-1.3408***	-1.4871***		-1.4942**	-1.5142**	-1.4585***		-1.6412***
	(0.3660)	(0.3207)	(0.1812)	(0.3774)	(0.4212)	(0.3442)	(0.4070)		(0.6174)	(0.6007)	(0.5293)		(0.3646)
$Yield_{t-1}$ (ln)									-0.3276	-0.4097	-0.3011		
									(0.4681)	(0.5869)	(0.6795)		
$Yield_{t-2}$ (ln)										0.1227	0.4104		
										(0.3659)	(0.3838)		
$Yield_{t-3}$ (ln)											-0.5545		
											(0.7272)		
Historical yield (ln)												-1.7481***	
												(0.3818)	
CAT events													
Flood	0.4967		0.5727	0.4460	0.3759	0.0739	0.0335	-0.1076	0.4062	0.4056	0.4227	0.3248	0.4676
	(0.5638)		(0.5675)	(0.6241)	(0.6070)	(0.4803)	(0.3770)	(0.3902)	(0.5856)	(0.5845)	(0.5876)	(0.5931)	(0.5605)
Drought	0.2140		0.2059	0.2445	0.3118*	0.3317***	0.2511***	0.2892***	0.2964**	0.2987**	0.2870**	0.3008**	0.2242
	(0.1370)		(0.1588)	(0.1664)	(0.1693)	(0.1272)	(0.0943)	(0.1012)	(0.1350)	(0.1369)	(0.1380)	(0.1354)	(0.1382)
Frost	0.9034***		0.8564**	0.9146***	0.6713**	0.0519	-0.0266	-0.0476	0.8870***	0.8879***	0.9015***	0.9219***	0.6529***
	(0.3305)		(0.3811)	(0.3477)	(0.3114)	(0.0739)	(0.0310)	(0.0350)	(0.3327)	(0.3341)	(0.3371)	(0.3415)	(0.2398)
Flood (nbr)		0.1694											
		(0.2629)											
Drought (nbr)		0.0025											

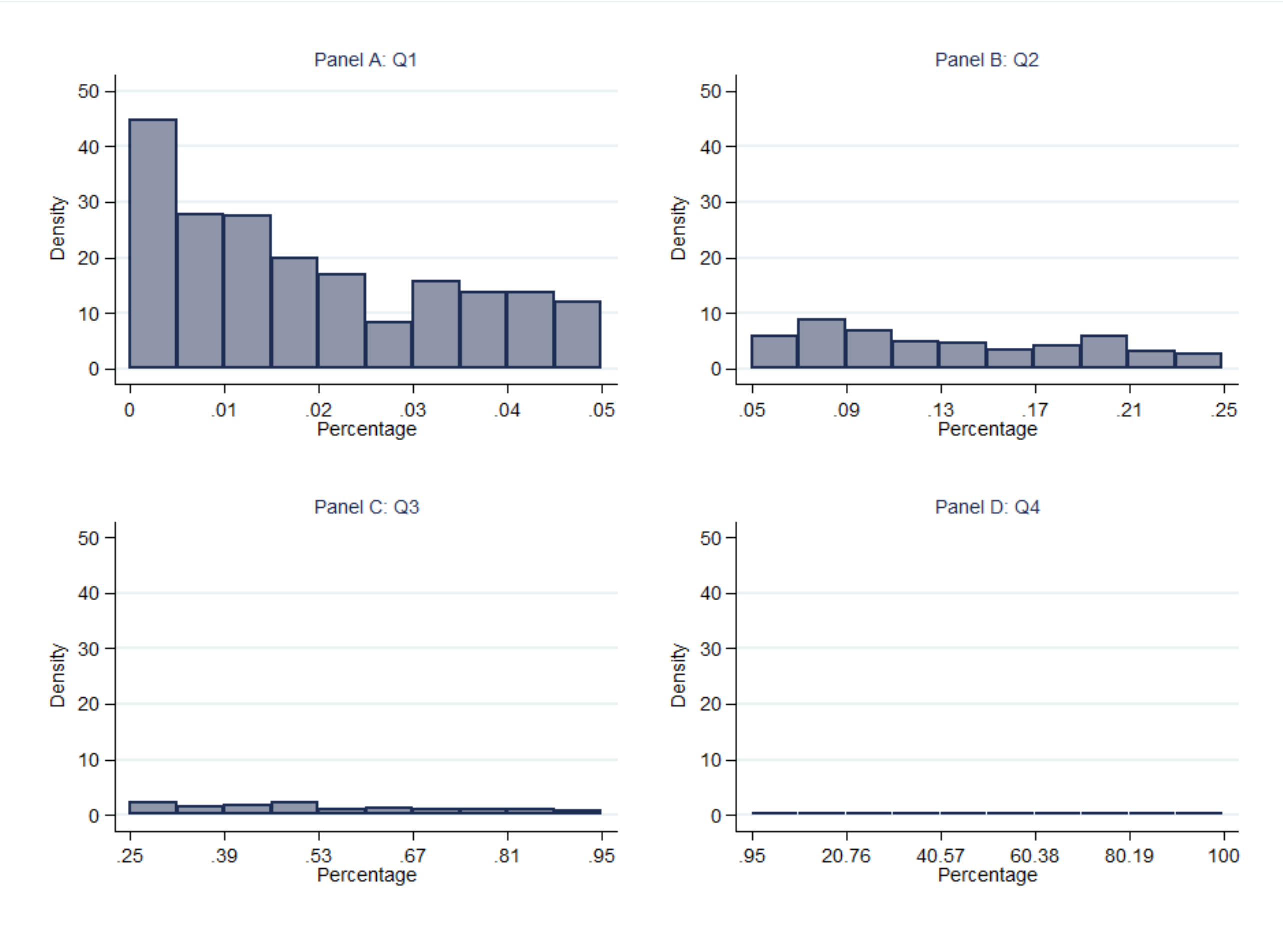
		(0.0018)											
Frost (nbr)		0.0317**											
		(0.0113)											
$Flood_{t-1}$													0.9564
													(0.5905)
$Drought_{t-1}$													0.0607
													(0.1023)
$Frost_{t-1}$													0.5917***
													(0.2153)
Constant	0.7896		-1.2779*	0.6905	1.6259	1.1767	1.7025	1.3811***	1.8202**	1.7759**	2.0043**	1.7045*	0.7787
	(0.9205)		(0.6905)	(0.9093)	(1.0371)	(0.9428)	(1.2118)	(0.1167)	(0.7986)	(0.8515)	(1.0037)	(0.9220)	(0.9142)
Fixed effects	Crop	Crop	No	Crop, year	Region group, crop, year	Region, crop, year	Province, crop, year	Province, crop, year	Crop	Crop	Crop	Crop	Crop
Observations	283,169	283,169	283,169	283,169	283,169	283,169	283,169	283,169	276,561	275,810	273,968	273,968	283,169
R-squared	0.26	0.31	0.17	0.28	0.29	0.41	0.48	0.44	0.22	0.22	0.22	0.21	0.26

Notes: Ordinary Least Square (OLS) estimates. Standard errors, clustered at province-crop level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Heterogenous structure of the insurance market

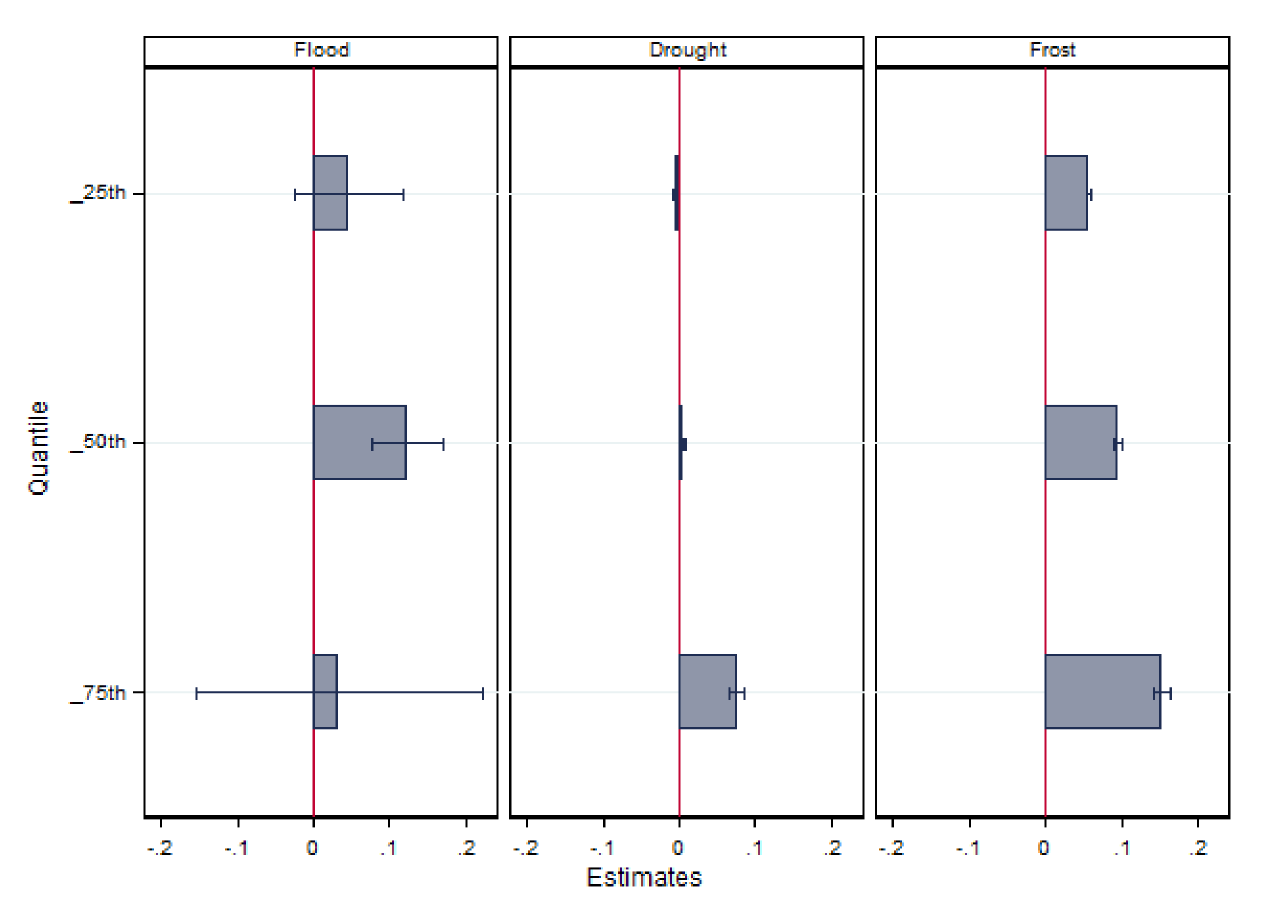
The share of insured value of production is highly heterogenous across crop-by-province combinations and tends to be concentrated in 25 percent of the sample (figure 2). The heterogeneity in concentrations of the insurance uptake reflects the structure of the Italian insurance market, characterised by the presence of a limited number of provinces –especially those in the North of Italy– and crops –generally the most valuable ones such as wine grapes– (e.g., ISMEA, 2020). For instance, shares of insured value of production lower than 0.05 percent (figure 2, panel A) are more common in the South (72 percent) than in the North (28 percent), vice-versa for shares between 0.25 and 0.95 percent (figure 2, panel C) where Northern provinces are dominant (66 percent). The increase in the share of insurance uptake overtime is basically associated with a growth in the insured values in the North and for most valuable crops[23].

Figure 2. Distribution of the share of insured value of production by quartile (Q).



Yu et al. (2021) recently suggest using a quantile regression approach to capture differential relationships across crop-by-province combinations characterised by different shares of insurance coverage[24]. Figure 3 presents the distributions of the estimated coefficients (and related confidence intervals) of CAT events by quantile[25].

Figure 3. Differential relationship between CAT events and insurance uptake.



Notes: Bars represent the magnitude of quantile regression estimates and capped spikes are the 95 percent confidence intervals of the coefficients for each quantile equation. The dependent variable is the share of insured value of production. All specifications include the natural logarithm of yield and premium, crop-specific fixed effects, a constant (omitted in the figure), and dummy variables proxying the occurrence of flood, drought, and frost events. The variable 'flood' is significant only at the 50^{th} percentile. The variable 'drought' is not significant at the 50^{th} percentile. Standard errors are clustered at province-crop level.

The positive association between the insurance uptake and frost events is confirmed. We also detect a significant increase in the insured uptake associated with an increasing occurrence of drought events. The estimated semi-elasticities suggest that the insurance demand is relatively more responsive to the incidence of frost than of drought events. The coefficient estimates range from -0.0057 to 0.0757 for drought and between 0.0565 and 0.1538 for frost. The difference of estimated coefficients across quantiles indicates that there is an increasingly positive effect for higher quantiles as compared to lower ones[26]. This suggests that crop-by-province combinations with larger shares of insurance tend to be increasingly responsive to the occurrence of drought and frost events.

Table 4 shows the changes in crop insurance coverage in response to the occurrence of CAT events, computed as the difference between the level of insurance uptake predicted at sample-specific average premium and yield in the unrestricted (Ω) and restricted (ω) model.

Table 4. Latent changes in the insurance uptake due to CAT events.

	OLS	QR		
		25th	50th	75th
Latent changes (%)	2.8	0.1	0.4	1.2

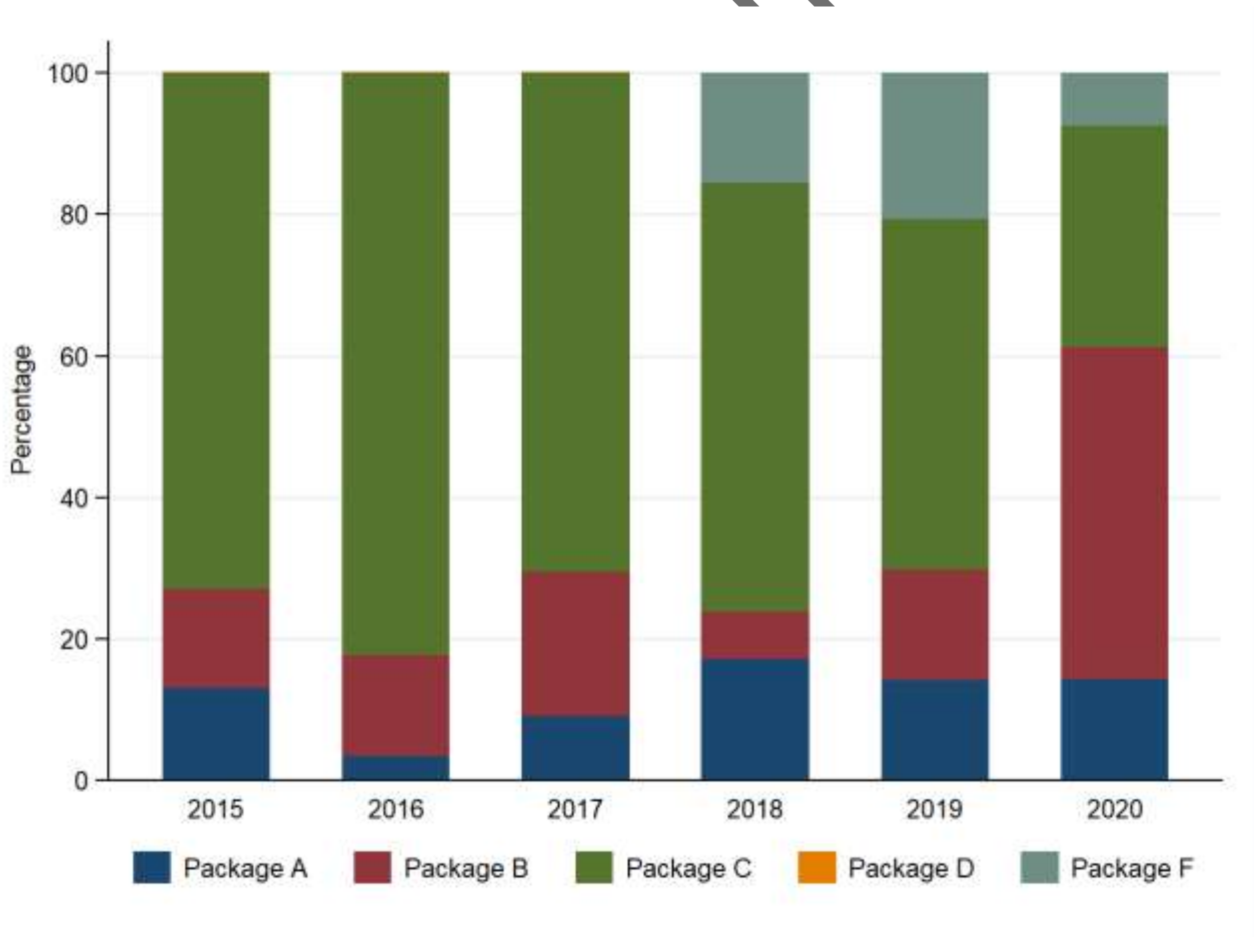
Notes: Latent changes obtained as the difference between the level of insurance uptake predicted at sample-specific average premium and yield in the unrestricted (Ω) and restricted (ω) model estimated through Ordinary Least Square (OLS) and quantile regression (QR).

Insurance increases by 2.8 percent in response to the occurrence of CAT events, suggesting that an increasing occurrence of CAT events may incentivise the participation in the insurance schemes. The incidence of CAT events tends to stimulate much more the larger shares of insured value of production.

Contracts covering catastrophic adversities

Since 2010, policymakers subsidised insurance contracts offering coverage against CAT events but left farmers free to choose types and combinations of adversities (CAT, frequency, accessory) to insure through mono-, multi-, or multi-risks contracts (see Section 2). The number of contracts stipulated against CAT events is difficult to isolate. In 2015, the major reform introducing more flexible and differentiated contracts allowed to clarify the type of adversity under coverage (Santeramo et al., 2022). Packages A, B, and D offering coverage against CAT events are complemented by packages C (one of the most signed contracts, figure 4) and F.

Figure 4. Distribution of insurance values by type of contract.



Source: Elaboration on data from ISMEA.

Notes: Adversities covered are catastrophic, frequency, accessory in package A; catastrophic and frequency in package B; frequency and optionally accessory in package C; catastrophic in package D; frequency in package F.

Table 5 reports the estimates of equation (1) on a subsample that includes observations from 2015 onwards, when the insurance packages entered into force. The dependent variable is the share of insured production value associated with different contracts. Column (1) considers all insurance contracts, column (2) focuses on contracts covering CAT risks (corresponding to packages A, B, and D), and column (3) refers to contracts not covering CAT risks (corresponding to packages C and F). We employ the OLS estimator, which is appropriate in this setting because the objective is to assess whether the association between CAT events and insurance uptake varies with the type of risk covered in insurance contracts.

As expected, the occurrence of frost events contributes to increase the uptake of insurance contracts covering against CAT adversities but has no effect on contracts specific for frequency adversities. The increasing occurrence of CAT adversities may push the uptake of contracts under packages A, B, and D whose performance tends to be systematically lower than contracts under packages C and F both in terms of insured values (i.e., 572 million EUR as compared to 681 million EUR) and of shares of insured value of production (i.e., 46 percent as compared to 63 percent on average).

Table 5. Drivers of insurance uptake, by type of contracts.

	Contracts		
	All	Covering CAT	Not covering CAT
Variables	(1)	(2)	(3)
Premium	0.5917***	0.4125***	0.4155***
	(0.1390)	(0.1244)	(0.1223)
Yield	-1.6628***	-1.3912**	-0.7851*
	(0.5346)	(0.6266)	(0.4158)
Flood	0.6877	0.1795	0.9775
	(0.7803)	(0.6227)	(0.8380)
Drought	0.0582	-0.0993	0.2716
	(0.2193)	(0.1531)	(0.2392)
Frost	1.5522**	1.4166**	0.5381
	(0.6287)	(0.6599)	(0.3913)
Constant	0.4047	0.7510	-0.4892
	(1.5052)	(1.5923)	(1.0929)
Fixed effects	Crop	Crop	Crop
Observations	151,359	151,359	151,359
R-squared	0.18	0.10	0.23

Notes: Ordinary Least Square (OLS) estimates. The dependent variable is the share of insured value of production. Specifications include the natural logarithm of yield and premium, dummy variables proxying the occurrence of flood, drought, and frost events, crop-specific fixed effects, and a constant. Standard errors, clustered at province-crop level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level. Contracts covering CAT events are packages A, B, D.

Conclusions and implications

This analysis explored a central question: Do CAT events influence participation in subsidised crop insurance, and which ones induce stronger market response? The demand for subsidised crop insurance is more responsive to idiosyncratic and frequent risks, such as frost, and less responsive to systemic and infrequent events, such as drought and floods. These findings highlight the importance of avoiding "on-size-fits-all" recipe to achieve resilience.

These insights are useful to operationalize a policy coherent agenda that balance crisis and risk management tools, as indicated in "The Vision for Agriculture and Food" (European Commission, 2025). Misalignments may arise when systemic risks are addressed through instruments designed for local or sub-national implementation. This would reduce the policy effectiveness.

Lessons can be drawn from Spain, United States, and *ex-post* compensation programs (e.g., Anton and Kimura, 2011; Turner and Tsiboe, 2022). In particular, crisis management tools and agricultural reserves should target crises induced by systemic CAT events that seem not to be a good fit for national crop insurance schemes.

Ensuring the availability of flexible, well-targeted insurance contracts, together with the expansion of public mutual funds such as Agri-CAT, can strengthen the resilience of European agriculture to climate change, support adaptation efforts, and improve the overall coherence of climate and agricultural policies. These results provide actionable evidence to support decision-makers in aligning risk management, climate adaptation, and resilience objectives across governance levels.

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[1] Data are sourced from the international disaster (EM-DAT) database, available at: https://www.emdat.be/.

[2] The European Union Solidarity Fund (EUSF), set up in the '70s to respond to major natural disasters, has been used for more than one hundred natural disasters (i.e., floods, forest fires, earthquakes, storms, and drought). The expenditure has grown exponentially, accounting, in three decades for more than 7.6 billion EUR. Major beneficiaries have been Italy, Germany, Croatia, and France). Data sourced from the EUSF website (https://ec.europa.eu/regional_policy/funding/solidarity-fund_en).

[3] The EU regulation 2115/2021 confirms the omnibus regulation (Reg. EU 2393/2017), allowing subsidisation up to 70 percent of the insurance premia for crop insurance schemes with damage threshold as low as 20 percent.

[4] Data sourced from the Agriculture and rural development section of the European Commission (https://agriculture.ec.europa.eu/system/files/2022-12/csp-at-a-glance-eu-countries_en.pdf).

[5] Hereinafter we will refer to 'insurance demand' or 'insurance uptake' as subsidised crop insurance demand or uptake.

[6] The European State of the Climate (2022), compiled through Copernicus data, flags Italy one of the EU countries most affected by drought, heavy rainfalls, and floods. (Source: https://climate.copernicus.eu/)

[7] The public expenditure under EU scheme is more than one hundred million EUR per year, distributed across more than 40 thousand beneficiary farmers. Data sourced from the European Court of Auditors (https://www.eca.europa.eu/Lists/ECADocuments/SR19_23/SR_CAP_Income_stabilisation_EN.pdf).

[8] The weather index insurance has been firstly introduced in the National Agricultural Insurance Plan 2017 (Ministerial Decree No. 31979 of December 30, 2016).

[9] The Agri-CAT Fund has been established with Law No. 234 introduced of December 30, 2021, and introduced in the Risk Management Plan in Agriculture 2023 (Ministerial Decree No. 64591 of February 08, 2023).

[10] Another strand of literature argues that crop insurance disincentivises climate change adaptation in agriculture (e.g., Wang et al., 2021).

[11] For a review of policy changes in the Italian system of risk management in agriculture see Santeramo et al. (2022).

[12] The support to mono-risk insurance contracts stopped with the introduction of the Agricultural Insurance Plan 2013 (Ministerial Decree No. 1934 of January 31, 2013).

[13] After the introduction of the Agricultural Insurance Plan 2014, pluri-risks insurance contracts offered coverage against at least three adversities among catastrophic, frequency, and accessory ones (Ministerial Decree No. 24335 of December 06, 2013).

[14] The expected insurance demand at time *t+1*, given the current information set Ω_t, is a function of yield and insurance premium at time *t*: $E[Q_{t+1}^D|\Omega_t] = f(Yield_t, Premium_t, \Omega_t)$. The information set includes both private knowledge, such as risk aversion and the familiarity with the insurance schemes, and shared knowledge, such as neighbours' experiences (e.g., Foster and Rosenzweig, 1995; Conley and Udry, 2010; Santeramo, 2019). We assume that Ω_t is proxied by the insurance demand at time *t*: Q_t.

[15] Introducing this driver in the demand equation, we obtain the following: $E\left[Q_{t+1}^{D^*}|\Omega_t\right] = f(Yield_t, Premium_t, Catastrophic\ weather\ events_t, \Omega_t)$.

[16] $E[Q_{t+1}^S] = g(Premium_t)$.

[17] The share of insured value of production captures both the extensive margin (participation in insurance) and the intensive margin (coverage intensity among insured producers). As a result, changes in this variable may reflect increased insurance take-up by previously uninsured farmers as well as adjustments in coverage levels by already insured producers. Due to data limitations, we

cannot separately identify these two margins, and results should therefore be interpreted as reflecting overall changes in insurance uptake and coverage.

[18] The analysis is conducted at the crop-by-province level and includes crop fixed effects, which account for time-invariant differences in crop-specific exposure to CAT events and baseline insurance patterns.

[19] The sensitiveness to the occurrence of CAT events is crop-specific (Tappi et al., 2023). Similar crops (e.g., cereals) tend to have analogous responses to CAT events, then crops with different growing needs (e.g., autumn-winter *versus* spring-summer crops such as cereals and tomatoes). If a province is characterised by the production and insurance of similar crops, the occurrence of events adverse to those crops will increase the responsiveness of insurance uptake of that province. Differently, the sensitiveness of insurance uptake to CAT events will be likely lower in provinces where the crop production and insurance are more diversified (e.g., cereals are more sensitive to frost events than tomatoes).

[20] The restricted empirical specification is as follows: $S_{ikt} = \alpha_k + \beta Y_{ikt} + \gamma P_{ikt} + \varepsilon_{ikt}$.

[21] We have excluded olives insofar the lack of production data makes unfeasible the analysis.

[22] Consistent with the arguments of Goodwin (1993), among others, the positive coefficient estimated for premium suggests that high-risk participants prevail in the insurance market.

[23] In 2010 the top three provinces for insured value were Bolzano (103 billion EUR), Trento (51 billion EUR), and Foggia (38 billion EUR), whereas in 2020 we found only northern provides: Treviso (115 billion EUR), Verona (63 billion EUR), and Trento (28 billion EUR), again, exception made for Foggia, the top insured provinces are in the North. Changes in the top three insured provinces may be related to type of crops insured, which have been apple (156 billion EUR), tomato (40 billion EUR), and wine grape (14 billion EUR) in 2010, and wine grape (261 billion EUR), tomato (29 billion EUR), and corn (10 billion EUR) in 2020. Apples, traditionally produced in the provinces of Bolzano and Trento have been less insured in 2020 than in 2010. This reduction may be due to switch from insurance schemes (e.g., hail insurance) to on-farm strategies (e.g., anti-hail nets) (Rogna

et al., 2023). Also, the insured value of wine grapes has increased exponentially during the last decade (from 14 to 261 billion EUR) and concentrated in North-Eastern provinces, such as Treviso and Verona.

[24] We therefore estimate the following quantiles regression equation:

$$S_{ikt} = \alpha_k^{(p)} + \beta^{(p)} Y_{ikt} + \gamma^{(p)} P_{ikt} + \psi^{(p)} \boldsymbol{W}_{it} + \varepsilon_{ikt}^{(p)}$$

where $0 < p < 1$ indicates the proportion of the sample having scores below the quantile at p; variables and parameters are defined as in Section 3.

[25] Each specification also includes the natural logarithm of yield and premium, crop-specific fixed effects, and a constant, omitted for brevity in the figure and fully reported in table B.1 of the Section B of the Supplementary Material.

[26] The effect is about double between each quartile for frost and the increase is exponential between 50^{th} and 75^{th} quartile for drought.